Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia

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Acronyms and Abbreviations

A	heat exchanger area
A5	Article 5
AACT	Accelerated AC Efficiency Trajectory
AC	air conditioner
ASEAN	Association of Southeast Asian Nations
BAT	best available technology
BAU	business as usual
BKF	Badan Kebijakan Fiskal
BRESL	Barrier-Removal for Efficiency Standards and Labels
BUENAS	Bottom-Up Energy Analysis System
CES	carbon dioxide emissions savings
CaF	carbon factor
CFL	compact fluorescent lamp
CO_2	carbon dioxide
CSPF	cooling seasonal performance factor
DM	distributor markup
EBIT	earnings before interest and taxes
EER	energy-efficiency ratio
EESL	Energy Efficiency Services Limited
EL	efficiency level
EXV	electronic expansion valve
FCF	free cash flow
FEMP	U.S. Federal Energy Management Program
FSD	fixed-speed drive
GEF	Global Environment Facility
GHG	greenhouse gas
GPP	green public procurement
GW	gigawatt(s)
GWh	gigawatt-hour(s)
GWP	global warming potential
HE	heat exchanger
HFC	hydrofluorocarbon
HS	Harmonized System
HTF	High Tide Foundation
IDEA	International Database of Efficient Appliances
IDR	Indonesian Rupiah
IEA	International Energy Agency
INPV	industry net present value
ISO	International Organization for Standardization

kWh	kilowatt-hour(s)
LBNL	Lawrence Berkeley National Laboratory
LCC	life-cycle cost
MEMR	Ministry of Energy and Mineral Resources
MEPS	minimum energy performance standards
MLF	Multilateral Fund
MM	manufacturer markup
MOEF	Ministry of Environment and Forestry
MP	Montreal Protocol
MPC	manufacturer production cost
MSP	manufacturer selling price
MW	megawatt(s)
NEC	national energy consumption
NEqC	national equipment cost
NES	national energy savings
NOC	national operating cost
NOPAT	net operating profit after taxes
NPV	net present value
PAMS	Policy Analysis Modeling System
PLN	State Electricity Company
PP	purchase price
PPE	plant, property, and equipment
R&D	research and development
Rp	Rupiah
RT	refrigeration ton
S&L	standards and labeling
SG&A	selling, general, and administrative
SHINE	Standards Harmonization Initiative for Energy Efficiency
TEAP	Technical Economic Assessment Panel
TM	medium voltage
TR	low voltage
TWh	terawatt-hour(s)
TXV	thermostatic expansion valve
U	overall heat exchange coefficient
UA	product of overall heat exchange coefficient and heat exchanger area
U4E	United for Efficiency
UEC	unit energy consumption
UNDP	United Nations Development Program
U.S.	United States
VA	volt-ampere
VAT	Value-Added Tax
VRF	Variable refrigerant flow

VSD	variable-speed drive
W	watt(s)
WACC	weighted average cost of capital

Executive Summary

According to the International Energy Agency (IEA), energy use associated with space cooling tripled between 1990 and 2016, making it the fastest growing end-use in buildings (IEA, 2018). This rapid growth is influenced by conditions in developing countries including growing populations, increased urbanization, electrification, rising incomes, and prices falling for air conditioning (AC) equipment. In economies with increasingly hot climates, the growth in AC stock will have a large-scale impact on electricity generation capacity, peak load, and greenhouse gas (GHG) emissions if no additional policy measures are taken.

In October 2016, the Parties to the Montreal Protocol adopted the Kigali Amendment to phase down hydrofluorocarbons (HFCs). HFCs are a dangerous and fast-growing short-lived climate pollutant that are hundreds of thousands of times more powerful than carbon dioxide when present in the atmosphere, and are responsible for roughly 4 billion tons of CO_2 emissions every year.[1] Although not an ozone-depleting substance, the contribution of HFCs to global warming is enormous given that they can trap as much as 10,000 times as much heat as an equivalent molecule of carbon dioxide. Because they are short-lived climate pollutants, cutting HFCs from the atmosphere has an immediate impact, and can remove up to 0.5 Degrees Celsius alone. Improving the energy efficiency of ACs in tandem with the HFC phasedown can effectively double the benefits of the HFC phasedown under the Kigali Amendment (Shah et al., 2015).

Sales of ACs in Indonesia are forecasted to increase by 7.5% each year, which suggests that the peak demand could increase by over 20 GW by 2035 (McNeil et al., 2019). Large-scale deployment of highly efficient and increasingly affordable inverter-driven (variable-speed) ACs could reduce Indonesia's AC electricity use by 30%–50%. However, adoption of inverter-driven ACs has lagged in Indonesia: the technology constitutes only 8% of the Indonesian AC market, compared with 40% in Southeast Asia and 65% in China.

In this context, LBNL designed a technical analysis to support policy action to transform the market towards more efficient ACs (including with low- global warming potential (GWP) refrigerants) in the longer term. Setting longer-term targets in consultation with the AC industry is an approach that has been used very successfully in the context of refrigerant changes under the Montreal Protocol, under the treaty's well-known "start-and-strengthen" approach. Such an approach, particularly when pegged to policies aimed at mitigating costs of superefficient technology, serves as a positive investment signal to manufacturers, further reducing compliance costs for manufacturers and ultimately reducing the costs to consumers.

Almost all AC manufacturers supplying to the Indonesian market either import the full AC units from countries such as Thailand or China, or import the majority of the components. Furthermore, in recent years there has been an increasing concern in the Indonesian government about reducing the current

[1] HFCs are one of the fastest-growing greenhouse gases, increasing at a rate of 10-15% per year. (Velders et al., 2012).

account deficit.

The Association of Southeast Asian Nations (ASEAN) Standards Harmonization Initiative for Energy Efficiency (SHINE) program has supported Indonesia's AC roadmap to 2020. ASEAN SHINE was instrumental in fostering regional collaboration on such policies. However, the levels adopted by ASEAN SHINE can be strengthened to achieve far greater efficiency improvements beyond the 2020 target. Recently, Indonesia revised its minimum energy performance standards (MEPS) and Energy Label to include the ISO cooling seasonal performance (CSPF) metric, the ASEAN SHINE 2020 MEPS targets and a new 5-star category level, which will help move the market towards more efficient ACs. While this is a welcome update of the program, the untapped potential of AC efficiency remains very high in Indonesia. Thailand and Vietnam are in the process of revising their MEPS/label levels for ACs upward by ~20% from current levels (CLASP, 2019). China's 2022 MEPS are likely to have a CSPF that is twice as high as the 2020 MEPS level from ASEAN SHINE, and would result in 40% less annual energy use than Indonesia's 2020 MEPS level. As key ASEAN countries and China revise their MEPS upward, Indonesia cannot prevent the dumping of inefficient ACs from these markets without a more ambitious MEPS-and-label strategy.

In order to inform this strategy, we develop a technical analysis to promote the benefits of energy efficiency programs to all major stakeholders in Indonesia: consumers, government and manufacturers. We take an engineering approach to assess the current supply chain constraints (i.e. currently, inverter ACs are directly imported), and the economic impacts on manufacturers of transitioning to higher efficiency ACs, to identify opportunities to transform the market towards inverter ACs. First, we develop a cost-versus-efficiency curve based on more than 300 configurations of mini-split ACs rated at 0.75 refrigeration ton (9000 Btu/hr), calibrated using our IDEA market data and local manufacturer inputs. We use this cost curve and economic modeling to estimate the manufacturer costs and industry net present value (INPV) of higher MEPS levels. The change in INPV is highly positive and increasing for higher-efficiency variable-speed ACs, indicating that manufacturers will benefit most by switching their production to the variable-speed (inverter) technology. Achieving more modest efficiency levels requires similar investments, which manufacturers may not be able to recover through future revenues. Higher MEPS also provide larger consumer and national benefits. At the highest level analyzed (i.e., at the estimated technical potential), the power sector avoids 5GW of demand (worth an additional US 10 billion), 29.6TWh annual electricity savings by 2035 and up to 193 million metric tons of avoided CO_2 emissions between 2021-2035, while Indonesian consumers save over US$3.9 billion through 2035.

Our analysis suggests immediate rescaling of Indonesia's AC S&L program should be considered at the levels shown in Table ES-1, with longer-term levels as shown in Table ES-2 to align with ASEAN, China and other international markets.

Table ES-1. Proposed Indonesia AC MEPS and Labels (2021)

Star Level	Efficiency in CSPF	Equivalent
1 Star (MEPS)	12.68	20% above Indonesia MEPS (2020)
2 Star	15.43	Singapore (2020)
3 Star	20.79	Potential China MEPS (2022)
4 Star	24.96	China Grade 1 (2020)
5 Star	27.46	U4E[2] Top Tier

Table ES-2. Proposed Indonesia AC MEPS and Labels (2023)

Star Level	Efficiency in CSPF	Equivalent
2 Star (MEPS)	15.43	Singapore (2020)
3 Star	20.79	Potential China MEPS (2022)
4 Star	24.96	China Grade 1 (2020)
5 Star	27.46	U4E High Efficiency

One of the greatest concerns within Indonesia regarding ambitious MEPS and labels is the first cost impact to price-sensitive consumers, and the investments necessary to produce more efficient equipment. The report explores a complementary policy package intended to drive cost down and encourage adoption of efficient technology by consumers, and identifies areas for technical assistance that would support Indonesian government priorities. The policy package includes the following options:

- Consumer awareness and education program
- Green Public Procurement
- Buyer's Club programs
- Utility rebate programs and/or on-bill financing
- Manufacturer incentives

Consumer awareness and education program

To complement the increase in the MEPS and the rescaled 5-star label, Indonesia should implement large-scale consumer education and outreach on the many co-benefits of superefficient ACs. A significant barrier to efficiency after first-cost is lack of consumer awareness and education regarding

[2] The United Nations Environment Program (UNEP)'s United for Efficiency (U4E) Initiative has developed "model regulations" with the MEPS levels harmonized with China's 2022 MEPS level. The U4E Initiative is encouraging countries to implement an integrated policy approach through energy-efficient products to bring about sustainable and cost-effective transformation. U4E's model regulation provides guidelines and core requirements for energy efficiency, refrigerants, testing, and functional performance.

the savings and environmental benefits of efficient ACs. Although Indonesian manufacturers have designed consumer education programs, these campaigns have achieved mixed success according to in-country interviews. Preliminary research demonstrates that government-led large-scale education, outreach, and promotion is critical to success.

Green Public Procurement: Green procurement is the process of finding, buying, and obtaining services and technology that are environmentally friendly while replacing outdated technology. Through Green Public Procurement (GPP), the Indonesian government can directly demonstrate the process of transitioning to environmentally-friendly technology and the benefits of the implementation. The Ministry of Environment and Forestry (MOEF) has adopted a plan for green public procurement and begun an inter-agency consultation process to roll out the green procurement requirements progressively in various provinces. The current requirements also refer to the AC star-rating program and the current label. Because there are plans for addition of a fifth star to the labeling program, we recommend that the green procurement also consider adoption of the 5-star level for public procurement. As explained below, green procurement will be more powerful when linked to a private buyer's club launch, and encourage competition as well as public recognition.

Buyer's Club: A buyer's club is a form of demand aggregation. Demand aggregation programs are a powerful tool to quickly transform markets where cost is a barrier. A buyer's club is a coalition of purchasers who pool resources to purchase a product in bulk quantities, to spur an economy of scale. A single purchase from a buyer's club of more efficient ACs increases overall demand and economies of scale, which in turn makes that product more accessible and affordable to the average buyer. A potential pilot is to start with a large hotel chain, which could rely on a hotel association as an aggregator, and the major utility company as a partner. In this example, if the hotel chain agrees to purchase only the more efficient 5-star ACs, this could provide a guaranteed market to AC manufacturers, provide economies of scale for more efficient technologies, and reduce costs to all consumers of more efficient equipment.

With any potential buyer's club, it will take significant effort to pool resources and put the correct elements in place to achieve the outcome. It is recommended to organize the buyer's club with energy efficiency requirements in common with other programs, and notably the existing green public procurement program led by the MOEF. In this case, given that Indonesia has an already strong start to its GPP, it makes sense to coordinate the launch of a buyer's club in tandem with the government rollout of the GPP. This type of coordination would ensure that these economies of scale build off of one another, and reinforce market signaling such as high-level and well-publicized commitments, and garnering government buy-in, to name just two.

Rebate and Utility-Based Programs: Policies such as rebates and utility programs for efficient ACs can drive down the first-cost barrier for consumers while allowing utilities to more effectively meet rising electricity demand. This is particularly significant in Indonesia given the rapid increase in AC consumption and resultant higher peak load demands that the country will continue to experience. Reducing demand – including peak load demand – is critical for Indonesian utilities. Cash-back rebates given upon purchasing a superefficient AC unit will further reduce costs and encourage consumer adoption of efficient technology. Utilities can subsidize energy efficient technology for a consumer, that is then repaid through monthly installments. LBNL will further explore incentives to determine applicability and strategy for implementation in Indonesia.

Manufacturer Incentives While manufacturers are concerned with the up-front cost of innovating and updating their technology to make energy efficient AC units, there are multiple manufacturer incentives that can be implemented to remove these concerns. Incentives can include subsidies, rebates, or tax credits. These types of manufacturer incentives are designed to “pull” the market towards energy efficient technology. We recommend that the government fund manufacturer incentives, for example, through reduction in value-added taxes (VAT) for energy efficient 5-star appliances (including but not limited to ACs) levied by the Fiscal Policy Agency or Badan Kebijakan Fiskal (BKF), a unit under the Ministry of Finance. By encouraging domestic manufacturing of efficient ACs as well as reducing equipment imports, such an incentive could reduce the government’s current account deficit and increase revenue.

Within the past two years the Montreal Protocol (MP) Parties have explored funding, technology opportunities and challenges regarding energy efficiency in refrigeration and air-conditioning. While there may be additional incentives through the MP, this funding mechanism is not well-tested and it is not yet clear whether this is a source or regime that manufacturers can rely upon in the near future.

The debate about how to co-fund energy efficiency improvements while phasing down HFCs under the Kigali Amendment is evolving and ongoing, the Quito Decision presents an opportunity for A5 Parties such as Indonesia to implement well-designed demonstration projects to showcase to other A5 Parties how to both (1) phase out high-GWP refrigerants that contain HFCs, while simultaneously (2) increase the energy efficiency of AC equipment.

Indonesia would benefit from setting a long-term GWP target consistent with the United Nations, United for Efficiency (U4E) model regulation guideline levels of 750 for split systems, and 150 for self-contained AC systems. A well-designed AC model does not have to trade-off between efficiency and refrigerant transition, since both R32 and R290 alternate low-GWP refrigerants are more efficient than the baseline R410A and R22 refrigerants respectively. Transitioning simultaneously to low-GWP refrigerants along with implementing energy efficiency improvements for ACs is likely to keep implementation costs (and therefore costs to the consumer) lower than implementing these separately. LBNL will further explore the potential for designing a project to demonstrate energy efficiency improvement in ACs along with the transition to low-GWP refrigerants in Indonesia.

1 Introduction

According to the International Energy Agency (IEA), energy use associated with air cooling tripled between 1990 and 2016, making it the fastest-growing end use in buildings (IEA, 2018). This rapid growth has been influenced by conditions in developing countries, including increased urbanization and electrification, rising incomes, and falling prices for air conditioners (ACs). IEA estimates roughly 1.6 billion ACs installed in buildings around the world, and it projects 5.6 billion ACs by 2050 (IEA, 2018). AC sales in key emerging high-population economies—such as Indonesia, Brazil, and India—are growing at 10%–15% per year (BSRIA, 2014; Shah et al., 2013, 2015). Indonesia, India, and China are expected to contribute over half of the projected growth in space cooling energy use by 2050 (IEA, 2018). Indonesia is Southeast Asia's largest energy consumer, accounting for over 36% of the region's energy demand. Its electricity consumption is expected to increase 8%–9% annually, with rapid AC adoption contributing significant demand (Letschert et al., 2017). Between 2015 and 2030, 75 million AC units may be added to Indonesia's AC stock (Letschert et al., 2017).

In economies with hot climates, the growth in AC stock will have a large impact on electricity generation capacity, peak load, and greenhouse gas (GHG) emissions if no additional policy measures are taken. However, effective efficiency policies could mitigate the impact. For example, shifting Indonesia's 2030 stock of room ACs away from low-efficiency equipment relying on refrigerants with high global warming potential (GWP) toward higher-efficiency ACs with low-GWP refrigerants might save 20–46 gigawatts (GW) of peak load, avoiding 40–93 500-MW peak power plants (Nihar Shah et al., 2015). Stringent energy efficiency standards and labeling (S&L) programs are one policy option. Compared with S&L programs in other Southeast Asian countries, Indonesia's S&L program is unambitious, which leaves a large portion of the energy-efficiency savings potential untapped (Letschert et al., 2017). However, some stakeholders and policymakers express concern about ambitious energy-efficiency policies owing to potential upfront cost impacts on price-sensitive consumers and concerns about the investments necessary to produce more efficient equipment.

Reducing use of hydrofluorocarbons (HFCs) as AC refrigerants is also critical for climate change mitigation. HFCs have a GWP tens of thousands of times higher than that of carbon dioxide (CO_2), and they account for the equivalent of roughly 4 billion metric tons of CO_2 emissions every year.[3] In October 2016, the Parties to the Montreal Protocol adopted the Kigali Amendment to phase down HFCs. Improving AC energy efficiency in tandem with the HFC phasedown can effectively double the benefits of the phasedown; in the room AC sector alone, eliminating HFCs while increasing energy efficiency could avoid about 98 billion metric tons of cumulative CO_2 emissions globally by 2050 (Nihar Shah et al., 2015).

The Parties to the Montreal Protocol also adopted Decision XXVIII/3, requesting inter alia the Technical Economic Assessment Panel (TEAP) to review energy-efficiency opportunities in the refrigeration and AC sectors related to a transition to climate-friendly alternatives. In Decision XXX/5 the Parties enabled

[3] HFCs are among the fastest-growing GHGs, increasing at a rate of 10%–15% per year (Velders et al., 2012).

Article 5 Parties (developing economies), including Indonesia, to spend part of their Montreal Protocol funding for energy-efficiency policy training and support and for promoting access to energy-efficient technology. Within the past 2 years, TEAP has issued several reports, and the Parties have held events at multiple Montreal Protocol meetings to explore funding, technology opportunities, and challenges regarding energy efficiency in the room AC sector.

Indonesia is among the many developing countries tasked with creating policies and programs aligned with the Kigali Amendment and related energy-efficiency decisions, including freezing HFC production and consumption in 2024. Rising temperatures, longer summers, crop shortages, extreme weather events, and rising sea levels have fostered growing awareness among Indonesian policymakers of the need to adopt climate-friendly refrigerant alternatives and aggressive energy-efficiency strategies—particularly because rising temperatures will otherwise drive increasingly high energy demands, especially during peak-use times.

In this context, Lawrence Berkeley National Laboratory (LBNL) designed the Accelerated AC Efficiency Trajectory (AACT) to support policy action transforming markets toward high-efficiency ACs in the long term. Setting long-term targets in consultation with the AC industry has proven effective for refrigerant transitions under the Montreal Protocol. Such an approach—particularly when it targets cost reductions for energy-efficient technology—can provide a roadmap and investment certainty to manufacturers, thereby reducing manufacturers' compliance costs and ultimately the costs to consumers.

The AACT project described in this report, written in collaboration with the Technology Institute of Bandung, has several purposes: (1) analyze the AC market in Indonesia to understand AC types, efficiency levels (ELs), and projected growth levels; (2) develop a techno-economic analysis of AC equipment; and (3) develop minimum energy performance standards (MEPS) and complementary program recommendations that reduce costs and promote energy-efficient ACs in Indonesia, along with a long-term MEPS target in line with key markets (e.g., China and the United States) that captures high-efficiency cost reductions due to economies of scale.

After an overview of current AC policies and programs in Indonesia (Section 2) and a description of our analytical framework (Section 3), Sections 4 through 9 of the report focus on the following analyses:

- **Market assessment**—characterizing market trends, quantities of equipment sold (imports vs. locally manufactured), efficiencies, industry structure, and manufacturer and product market shares.
- **Energy-use analysis**—assessing potential energy savings from higher AC efficiency, forming the basis for energy-savings values used in the life-cycle cost (LCC) and subsequent analyses.
- **Engineering analysis**—establishing the relationship between manufacturing production cost and AC efficiency as a basis for cost/benefit calculations for individual users, manufacturers, and the nation.
- **LCC analysis**—analyzing the tradeoff between higher upfront costs and lower utility bills, including future savings scaled by a discount factor that accounts for preferences for immediate over deferred gains.

- **National impact analysis**—enabling policymakers to consider the nationwide magnitude of efficiency impacts based on AC sales and stock.
- **Manufacturer impact analysis**—estimating the MEPS impact on Indonesian AC manufacturers based on a cash-flow model adapted for Indonesia and the AC industry, in the style of the analysis performed for U.S. appliance-efficiency standards. The model evaluates how MEPS can impact local manufacturers in terms of investments, production costs per unit, and revenues resulting from changes in sales or prices. Key inputs include industry cost structure, sales, and pricing strategies. The key output is the industry net present value (INPV) in various policy scenarios.

Impacts are described for a set of ranked ELs, from Indonesia's current baseline to the best available technology (BAT). The impact analyses provide the basis for revising the MEPS and label design for ACs in Indonesia in Section 10. Section 11 recommends policies and program designs for complementary policies that support market transformation. Complementary actions include the following:

- Consumer awareness and education program
- Green Public Procurement
- Buyer's Club programs
- Utility rebate and/or on-bill financing programs
- Manufacturer incentives

This report presents the most current scenario analysis and considerations for policies and programs supporting AC market transformation in Indonesia. The recommendations will be updated in consultation with stakeholders during the remainder of the project.

2 AC MEPS and Energy-Efficiency Labels in Indonesia and Major Markets

The Indonesian Ministry of Energy and Mineral Resources (MEMR) implements energy-efficiency and conservation programs through the development of MEPS and energy-efficiency labels (MEMR, 2018). MEPS set an efficiency floor whereby it is illegal to import or offer for sale models that exceed the efficiency limit contained in the regulations as of a specified date. The MEMR label is a comparative label that provides consumers with an easy to understand tool to compare the energy efficiency of similar sized models. The Indonesian label uses a scale of 1 to 4 stars, where 4 is the most efficient and 1 is the MEPS level. Figure 1 shows the MEMR label for room ACs.

Figure 1. MEMR 4-Star Energy Label

Compact fluorescent lamps (CFLs) and ACs are the only appliances regulated by MEMR. Various electricity consuming products including refrigerators, fans, rice cookers, and motors which were covered under draft regulations developed with support from the Barrier-Removal for Efficiency Standards and Labels (BRESL) program, which ended in 2013 were not adopted at the time (United Nations Development Programme (UNDP), 2015). MEMR is in the process of developing draft regulations for MEPS and 5-star labels for those products.

Indonesia's first AC MEPS were issued in 2015 and went into effect in August 2016 (MEMR, 2015b). This regulation mandated a minimum EL—assigned a 1-star rating—of 8.53 Btu/W/hr EER.[4] At the high end of efficiency, a 4-star AC was required to have an EER of 10.41 (MEMR, 2015b).

Based on the 2015 regulation, Indonesia's AC performance test references Indonesian National Standard (SNI) 19-6713-2002, which is consistent with International Organization for Standardization (ISO) 5151:1994. The AC efficiency is based on a measured EER value. For non-inverter-type (fixed-speed) ACs, the measurement is taken at full load. For inverter-type (variable-speed) ACs, the

[4] We use the term energy-efficiency ratio (EER), defined as the ratio of total cooling capacity to effective power input to the device at any given set of rating conditions. For rating AC performance based on ISO Standard 5151, 1 W is equivalent to 3.412 Btu/hr.

measurement is taken at full load and 50% load based on the following calculation (MEMR, 2015b):

$$EER = 0.4 \times (EER\ full\ load) + 0.6 \times (EER\ 50\%\ load)$$

Table 1 shows the EER criteria for receiving different levels of star labeling (MEMR, 2015b).

Table 1. Indonesia's 4-Star Labeling and MEPS Requirements for ACs (2015 and beyond)

1 star (MEPS)	2 stars	3 stars	4 stars
$8.53 \leq EER < 9.01$	$9.01 \leq EER < 9.96$	$9.96 \leq EER < 10.41$	$10.41 \leq EER$

Unit: Btu/hr/W

The Association of Southeast Asian Nations (ASEAN) Standards Harmonization Initiative for Energy Efficiency (SHINE) program has worked with all ASEAN economies to harmonize standards across the region, and it has supported Indonesia's AC MEPS. The goal of this harmonization initiative is to have a common test method and set of MEPS and tiers for use in each country's comparative label. This harmonization has multiple potential benefits which include: a) reduced manufacturer burden as they only need to test their product once in order to sell their product in multiple countries, and b) having single MEPS levels allows for economies of scales, reducing further manufacturing and supply chain costs, and thereby reduce the price at retail.

The result of the collaboration is a roadmap assigning increasingly stringent MEPS over time (Table 2). However, these targets—even through 2020—remain below the MEPS China adopted in 2010 (3.20 W/W or 10.91 Btu/hr/W). Because China manufactures about 70% of the world's room ACs[5], and its domestic market accounts for roughly 30% of global AC sales, the low ASEAN SHINE MEPS fail to capture the economies of scale, low upfront costs, and significantly higher life-cycle savings and environmental benefits that could be realized by aligning with China's MEPS.

Table 2. National Roadmap (MEMR, 2015a)

Period	MEPS (Btu/hr/W)	MEPS (W/W)
July 31, 2018	8.53	2.50
August 1, 2018 – July 31, 2020	9.01	2.64
August 1, 2020 and beyond	9.96	2.92

Note: The MEPS consider the metric as defined above EER = 0.4 x (EER full load) + 0.6 x (EER 50% load)

Indonesia's current standards for mini-split ACs are based on EER for cooling efficiency. However, Indonesia recently adopted ISO 16358-1:2013, which defines the cooling seasonal performance factor (CSPF) metric, in SNI 8560-1:2018. Section 3.2 discusses energy-efficiency metrics.

Following the adoption of the CSPF metric, MEMR proposed a rescaling of the Label as follows:

[5] In general, window and unducted split ACs fall into the general rubric of "room ACs". The global room AC market is dominated by unducted split (known in the US as mini-split) ACs (Shah et al., 2013)

Table 3. Proposed Indonesia MEPS 2020 and label

Star	CSPF W/W Decree No. 57/2017	CSPF W/W Proposed Decree 2020	CSPF Btu/hr.W Proposed Decree 2020
*	2.65 ≤ CSPF < 2.8	3.10 ≤ CSPF < 3.4	10.58 ≤ CSPF < 11.60
**	2.8 ≤ CSPF < 3.1	3.4 ≤ CSPF < 3.80	11.60 ≤ CSPF < 12.96
***	3.1 ≤ CSPF < 3.24	3.80 ≤ CSPF < 4.20	12.96 ≤ CSPF < 14.33
****	CSPF ≥ 3.24	4.20 ≤ CSPF < 5.00	14.33 ≤ CSPF < 17.06
*****		5.00 ≤ CSPF	17.06 ≤ CSPF

Source: Public meeting held on December 19th, 2019

This update[6] allows for greater differentiation in the market between the MEPS/1-star level, consistent with the ASEAN SHINE target converted into CSPF, and the top of the market, which can be 60% more efficient than the baseline. This update is an improvement over current version of the label, and a first step to increase the penetration of efficient ACs with a CSPF greater than 17.06 Btu/hr.W. Nevertheless the untapped potential remains high and can be achieved beyond 2020.

Among regional markets, Thailand and Vietnam are in the process of revising their MEPS/label levels for ACs upward by ~20% from current levels (CLASP, 2019). Therefore it is important to consider the effect this regional market has upon Indonesia's ability to remain competitive within ASEAN.

Separately, China has revised its MEPS and labeling requirements for room ACs. The new proposed standard imposes five grades covering fixed- and variable-speed room ACs with Grade 5 as the MEPS for fixed-speed units, and Grade 3 as the MEPS for variable-speed units. According to the Green and high-Efficiency Cooling Action Plan and input from the Chinese National Institute of Standardization, the MEPS is expected to be combined for both AC types with Grade 3 as the threshold. China's 2022 MEPS are likely to have a CSPF that is twice as high as the 2020 MEPS level from ASEAN SHINE, and would result in 40% less annual energy use than the 2020 levels recommended by ASEAN SHINE.

The United Nations Environment Program (UNEP)'s United for Efficiency (U4E) Initiative has developed "model regulation guidelines" with the low efficiency levels harmonized with China's 2022 MEPS level and consistent with where major markets are anticipated to be headed. The U4E Initiative is encouraging countries to implement an integrated policy approach through energy-efficient products to bring about sustainable and cost-effective transformation[7]. U4E's model regulation provides guidelines and core requirements for energy efficiency, refrigerants, testing, and functional performance. The contents are designed for countries with no regulations or weak regulations to be able to easily adopt requirements that are harmonized with MEPS and labeling requirements in some of the larger markets around the world.

As noted above, harmonization with other economies is highly desirable. Hence, we consider the 2022 China MEPS and U4E levels as specific targets for harmonization in our impact analysis scenarios

[6] The update will be effective when a Ministerial Decree and its annex are signed respectively by the Minister of MEMR and the Directorate General of New and Renewable Energy and Energy Conservation

[7] The policy guides are available at: www.united4efficiency.org/resources

presented in the following sections.

3 Analytical Framework

3.1 Scope and Representative Units

To analyze the impacts of setting AC MEPS, we focus on a single AC model with a cooling capacity of 0.75 refrigeration tons (RT), equivalent to 9,000 Btu/hr. This model is representative of the small-capacity ACs (less than 1 RT or 12,000 Btu/hr) that are popular in homes with low volt-ampere (VA) connections and constitute approximately 80% of the Indonesian market (Letschert et al., 2017).

3.2 Energy-Efficiency Metric

In the 1990s and early 2000s, most countries adopted the EER metric for AC efficiency.[8] Since the mid-2000s, as variable-speed ACs increasingly have been adopted, seasonal energy-efficiency metrics have been regionally and internationally designed to estimate AC performance under regional climatic conditions that affect the amount of time ACs operate at part or full load. Seasonal metrics consider the impact of variations in outdoor temperature on cooling load and energy consumption, requiring multiple test points to compute a seasonally weighted average efficiency. They are intended to represent how ACs would perform over a typical cooling season in a representative building type with typical operating characteristics (Econoler et al., 2011). Seasonal metrics are increasingly used as an alternative to EER to set S&L requirements for ACs and heat pumps (Park et al., 2017).

The seasonal efficiency metrics used in Asian countries such as India and Japan are consistent with ISO 16358:2013-defined metrics, including CSPF, except they use their region-specific climatic conditions and minor adjustments, e.g. a different temperature from which cooling load starts to increase. Although Indonesia's current energy conservation standards for mini-split ACs are based on EER for cooling efficiency, our analysis considers ISO CSPF to support revision of the MEMR label based on ISO 16358-1.

The CSPF calculation for variable-speed units requires two sets of test data—measurement of performance (capacity and power input) at full- and half-capacity operation at an outdoor dry bulb temperature of 35°C—and then performance at 29°C can be calculated by ISO 16358-determined equations (Table 4). In this analysis, we calculate ISO CSPF based on performance data (measured according to ISO 5151 and 16358 standards) from commercially available 1 RT (12,000 Btu/hr) fixed-speed units as well as three 1-RT and one 0.75-RT variable-speed units using the ISO 16358 reference outdoor temperature bin hours—totaling 1,817 hours of data in the range of 21–35°C (15 bins, 1°C per bin).

[8] In the United States, a seasonal energy-efficiency metric for ACs was developed before 1990.

Table 4. Test Requirements and Options Used for AC Seasonal Energy-Efficiency Evaluation

Operating Condition/Type	Fixed	Variable
Full capacity (35°C)	Required	Required
Half capacity (35°C)	Not applicable	Required
Minimum capacity (35°C)	Not applicable	Optional[c] or not considered
Full capacity (29°C)	Required or optional[a]	Optional[b]
Half capacity (29°C)	Not applicable	Optional[b]
Minimum capacity (29°C)	Not applicable	Optional or not considered

[a] Although ISO 16358 requires full-load performance at the lower temperature to be measured, this is calculated in regional standards using predetermined equations:
$Capacity(29℃) = Capacity(35℃) \times 1.077$; $Power\ input(29℃) = Power\ input(35℃) \times 0.914$
[b] Performance at the lower temperature can be calculated using predetermined equations:
$Capacity(29℃) = Capacity(35℃) \times 1.077$; $Power\ input(29℃) = Power\ input(35℃) \times 0.914$
[c] ISO 16358 suggests the minimum capacity test at 29°C to be conducted first and allows the minimum capacity test at 35°C to be measured or calculated using default values.

3.3 Efficiency Level Definition

The impacts of setting MEPS depend on the current mix of efficiencies of equipment sold in the business as usual (BAU) scenario and in each MEPS scenario. Our model allows us to represent the current mix of equipment by characterizing the annual sales market distributions across seven ELs aligned with performance from the ASEAN SHINE roadmap, the potential China MEPS for 2022, regional best practices, as well as draft model regulation guidelines from U4E, shown in Table 5.

Table 5. ELs Considered in the Analysis

EL	Efficiency Rating in CSPF	Definition
EL0	10.57	Indonesia MEPS 2020 (ASEAN SHINE)
EL1	11.05	Indonesia 4-star (2018)
EL2	12.68	20% above Indonesia MEPS (2020)
EL3	15.43	Singapore 2020
EL4	20.79	Potential China MEPS (2022)
EL5	24.96	China Grade 1 (2020)
EL6	27.46	U4E High Efficiency
EL7	30.61	BAT

3.4 Analysis Period

Our model evaluates impacts over a period starting at the announcement of the MEPS and ending approximately 15 years after the MEPS effective date. We analyze the impacts of a MEPS that would take effect in 2021, with intermediate results in 2025, 2030, 2035.

4 Market Assessment

The market assessment gives an overall picture of Indonesia's AC market as defined in this study, including a characterization of market trends and quantities of equipment sold (imports vs. locally manufactured) as well as market shares by EL, industry structure, and manufacturer. It relies on manufacturers interviews carried out as part of this project and on three sources of publicly available data, which have been combined in (Letschert et al., 2017). First, data from the MEMR certification database provide registration numbers for products that have been certified to meet MEPS. The database comprises data from the certification body and test laboratories. Included in the data are applicant (importer/distributor, manufacturer), product brand, model number, product characteristics and features (cooling capacity, inverter), EER, and origin (locally produced or imported). The second source is the International Database of Efficient Appliances (IDEA), which was developed by LBNL to help resolve the lack of market data that has created a "major barrier to the optimal implementation of Indonesia's S&L program" (Gerke et al., 2015). The third source is based on retail surveys performed by the company Premise, which provide real-time macroeconomic data on the price and energy-efficiency labeling of AC units in Indonesia (Premise, n.d.). These survey data provide a "reality check" for the data in the IDEA database (Letschert et al., 2017).

4.1 AC Electricity Consumption

To clarify electricity consumption in Indonesia, we provide a snapshot of IEA electricity consumption data. Figure 2 shows the market share of electricity consumption from the commercial, residential, and industrial sectors in 2012 (OECD/IEA, 2015). In 2012, Indonesia's residential sector accounted for 41% of electricity consumption, the industrial sector 35%, and the commercial sector 24%. In 2016, the share of total electricity use from space cooling in residential and commercial buildings worldwide was 18.5% (IEA, 2018).

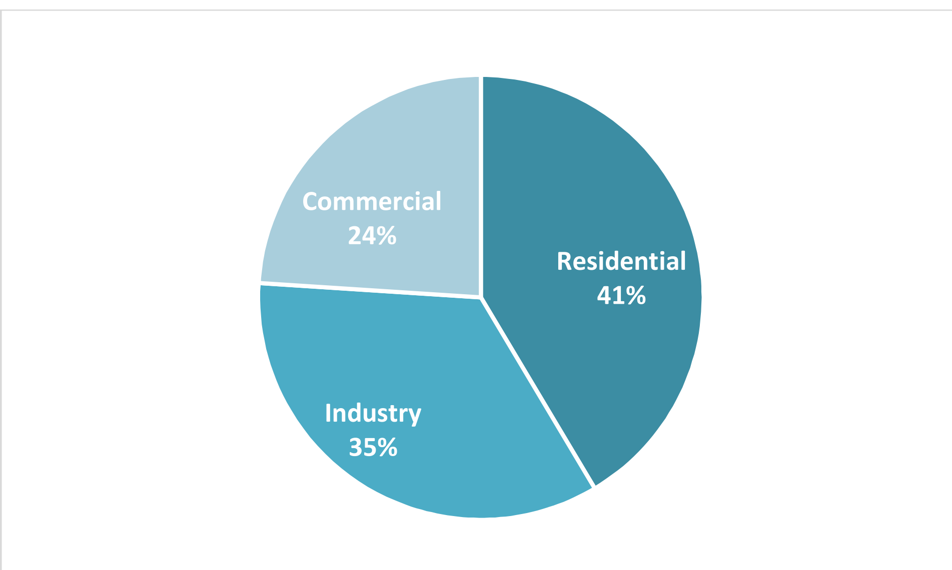


Figure 2. Share of Indonesia's electricity consumption by sector, 2012 (OECD/IEA, 2015)

To assess the Indonesian cooling sector, we use LBNL's Bottom-Up Energy Analysis System (BUENAS) model, a policy analysis tool that projects end-use energy demand for various equipment types and then aggregates those results to the end-use, sector, or national level. The model is designed to consider the likely impacts of specific efficiency policies at the global scale (McNeil et al., 2012).

Based on BUENAS outputs, Figure 3 (residential sector) and Figure 4 (commercial sector) show BAU growth projections for energy consumption.[9] Electricity consumption from residential room ACs is projected to increase tenfold between 2010 and 2030, with the room AC share of total residential electricity consumption increasing from 15% in 2010 to 43% in 2030. Electricity consumption from commercial space cooling is projected to more than triple between 2010 and 2030, with space cooling's share of total commercial electricity consumption increasing from 45% in 2010 to 49% in 2030. Combined, space cooling and room ACs are projected to account for 36% of total electricity consumption by 2030 (including Industry), up from 20% in 2010. As shown in (McNeil et al., 2019), these will have an even higher impact during peak hours, which will greatly increase the cost to the power sector and could also increase frequency of power outages.

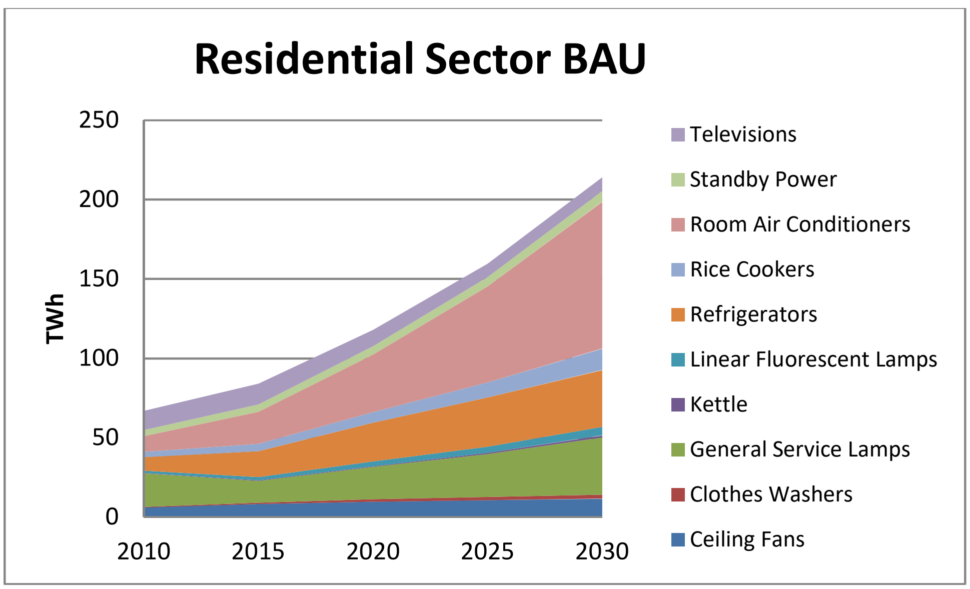


Figure 3. Residential electricity consumption under BAU scenario in Indonesia, 2010–2030

[9] The BUENAS BAU case includes growth in activity and intensity, along with product-specific assumption of efficiency (McNeil et al., 2012).

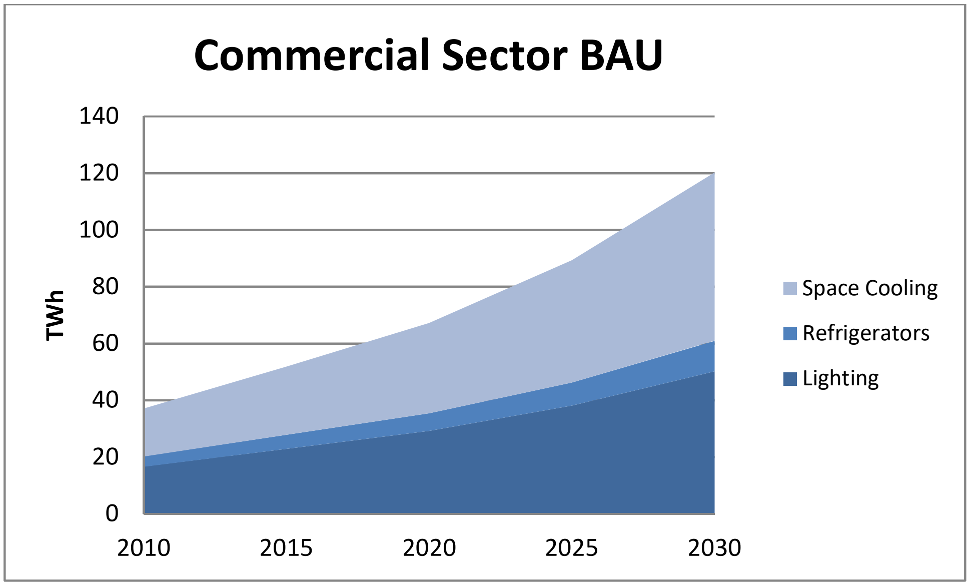


Figure 4. Commercial electricity consumption under BAU scenario in Indonesia, 2010–2030

4.2 Sales Estimates

A critical element of the market assessment is estimating the number of units entering the Indonesian market every year, because only ACs sold after the MEPS effective date will achieve the energy savings required by the standards. Figure 5 shows the unit sales of mini-split ACs in Indonesia during 2012–2017 (Euromonitor International, 2017). Sales increased from 2.56 million in 2012 to 2.9 million in 2013, dropped by 230,000 in 2014, and then continuously increased to 3 million in 2017.

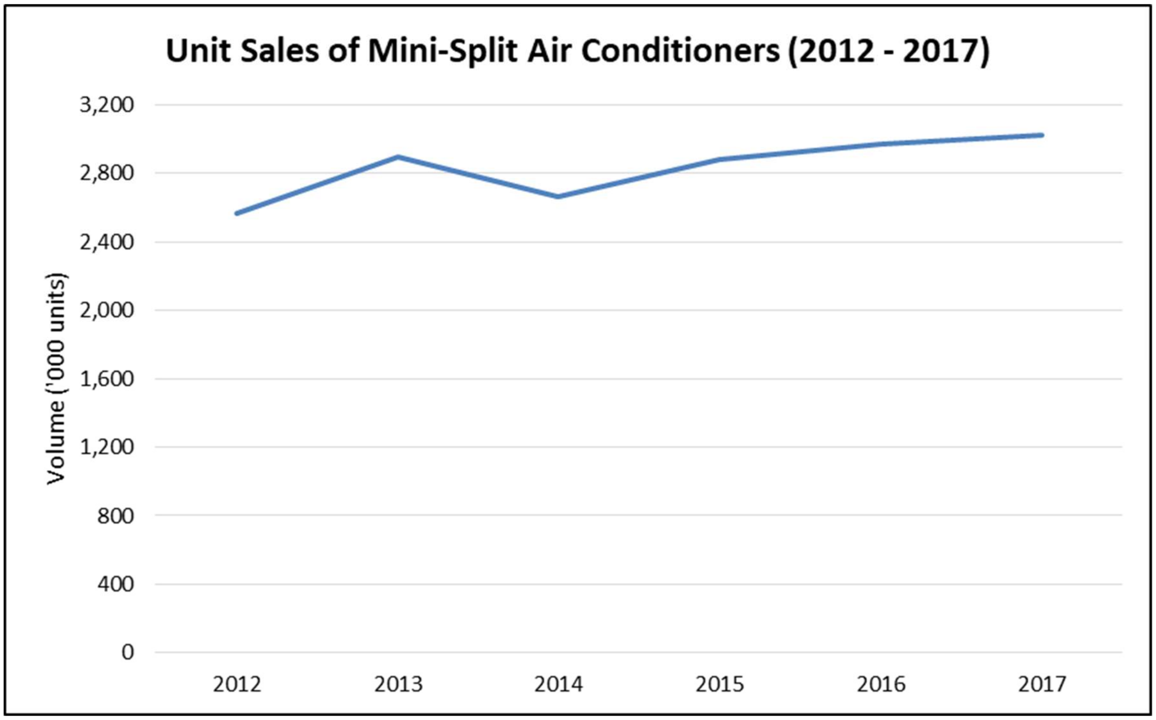


Figure 5. Unit sales of mini-split ACs in Indonesia, 2012–2017 (Euromonitor International, 2017)

The "Split Systems 2018 Indonesia" market report by the Building Services Research & Information Association (BSRIA) provides AC market sales data and projections from 2016 through 2022. Indonesia's overall AC market is projected to continue growing through 2022, fueled by the country's large and growing population, economic stability, and increasing purchasing power (BSRIA, 2018).

Manufacturer estimate that the market was around 2.6 Million units in 2018 and expected to reach 2.7 Million units in 2019. These estimates are more conservative but in line with the Euromonitor source used in the remainder of the analysis. The source also shows that only 8% of the overall market is made up of inverter-driven AC equipment, while 92% is non-inverter.

4.3 Imports and Local Manufacturing

Figure 6 shows the share of imports, based on trade value,[10] by country of origin in 2017: 48% of AC imports were from Thailand, 35% from China, and 16% from Malaysia. The imports represent about 89% of Indonesia's AC market - only 11% produced locally (BSRIA, 2014).

[10] We use the United Nations Comtrade Database (UNCOMTRADE, 2016) to estimate the trade value of AC imports to Indonesia. We use code 841510 from the Harmonized System (HS) to cover all the ACs included within the scope of the regulation: "HS 841510: Air conditioning machines; comprising a motor-driven fan and elements for changing the temperature and humidity, of a kind designed to be fixed to a window, wall, ceiling or floor, self-contained or split-system."

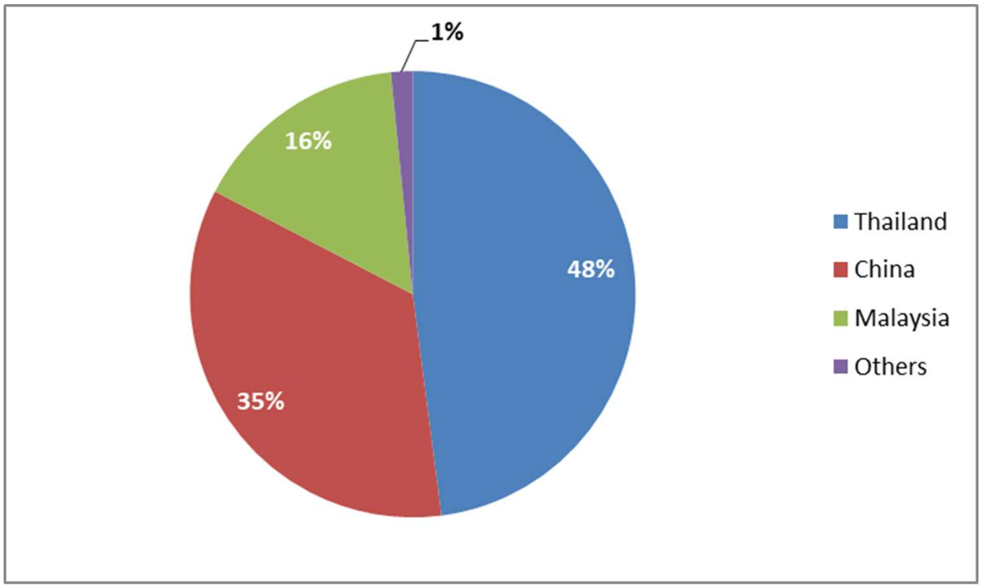


Figure 6. Share of ACs imported to Indonesia, by country of origin based on trade value, 2017

Although many manufacturers participate in the Indonesian AC market, the top five (Sharp, Daikin, Panasonic, LG, Samsung) account for over 80% of the mini-split AC segment by volume. Panasonic, one of the market leaders, produces mini-splits exclusively for the Indonesian market. Both Panasonic and Polytron produce mini-splits in their Indonesian-based factories. As of 2017, LG no longer had production in Indonesia, because it consolidated its production facilities in a strategic shift towards exclusively producing variable-speed units (BSRIA, 2018). As of June 2019, LG announced its intention to reverse this move and relocate some of their production of variable-speed ACs to Indonesia, as part of their investment consolidation plans in Southeast Asia[11]. Outside of these, almost all AC manufacturers supplying to the Indonesian market either import the entire AC units from countries such as Thailand or China, or input the majority of the components.

4.4 Efficiency Sales Distribution

Efficiency sales distributions are important for developing MEPS targets and high-efficiency labeling programs (Letschert et al., 2017). In Indonesia, more than 75% of AC products have the highest, 4-star rating, suggesting the need to increase Indonesia's AC energy-efficiency requirements, both for the MEPS and star levels (Figure 7). We convert the EERs from the MEMR certification database to calculate the Indonesian market's current mix of ELs in CSPF-equivalent (Figure 8; see Table 5 for EL descriptions). We show that Indonesia's AC efficiencies look high based on Indonesia's star rating system, whereas they look low, using the global EL levels.

[11] https://www.thejakartapost.com/news/2019/06/18/sharp-lg-to-relocate-factories-to-indonesia.html

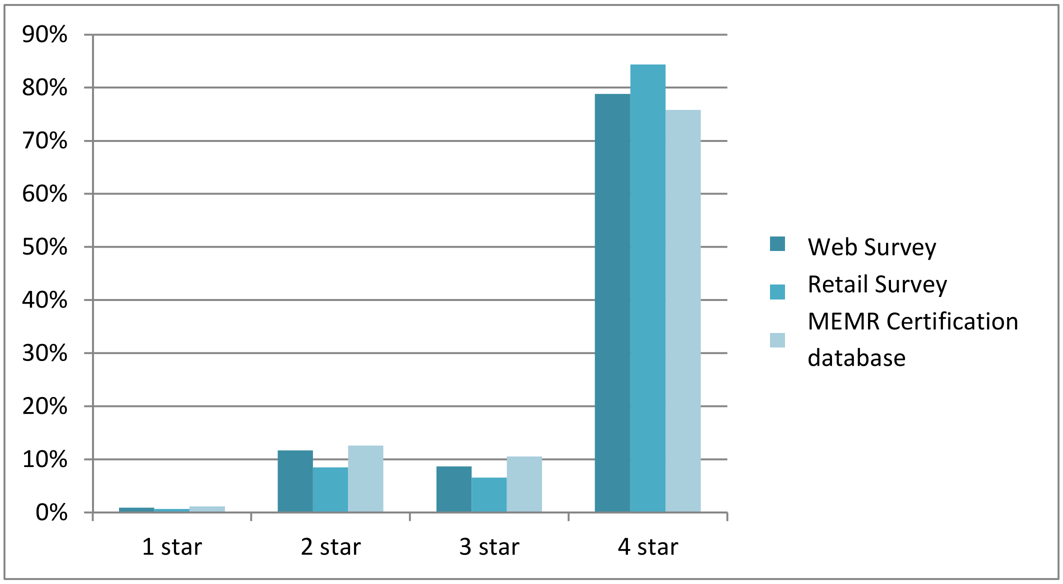


Figure 7. Indonesia's efficiency sales distribution by star label (2016-2017)
Source: authors' own elaboration based on IDEA

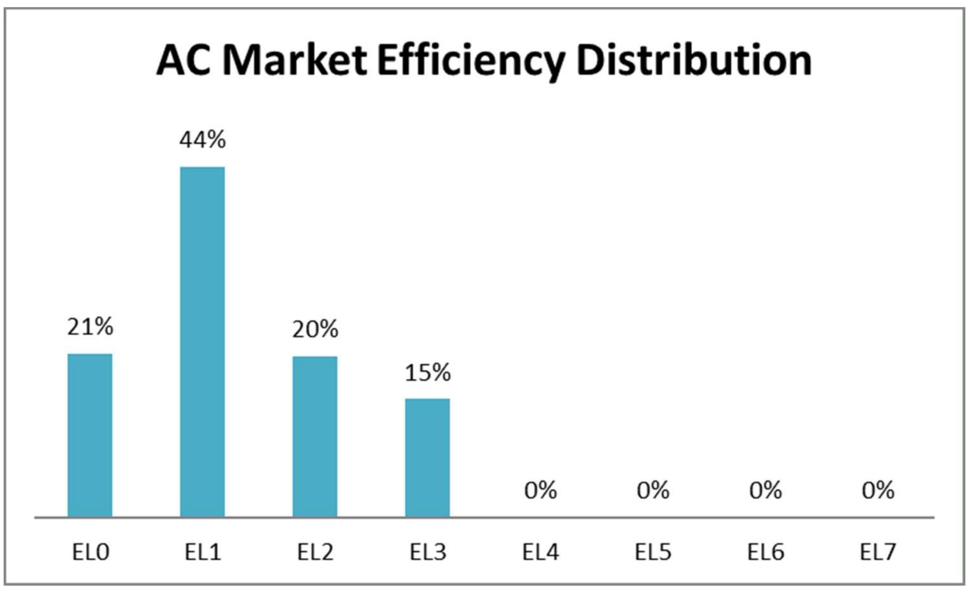


Figure 8. Indonesia's efficiency sales distribution by EL (see Table 5)(2016-2017)
Source: authors' own elaboration based on IDEA

5 Energy-Use Analysis

The energy-use analysis, which assesses potential energy savings from increasing AC efficiency, forms the basis for the energy-savings values used in the LCC and subsequent analyses. The goal of the energy-use analysis is to generate a range of energy-use values reflecting actual equipment use in the field. To estimate energy that would be used by new equipment operating at various ELs, the energy-use analysis uses the conditions described in ISO 16358:2013. We estimate average annual operating hours of ACs using inputs from the 2015 MEMR Energy Survey (MEMR, 2015a) for the residential sector (5.6 hr/day) and assuming ACs are run during business hours for the commercial sector (8hr/day). We find an average use of 6.6 hr/day. Table 6 shows key data inputs for the energy-use analysis. Table 7 shows the resulting annual unit energy consumption (UEC) values for the ELs considered.

Table 6. Key Data Inputs for Energy-Use Analysis

Input	Description	Value	Source
ELs	Distribution of efficiency (EL0–EL7)	Table 5	Analytical framework
Cooling capacity	Average cooling capacity (sales)	9,000 Btu/hr 0.75 RT	(Letschert et al., 2017)
Final users	% of AC users in residential (households) vs commercial sector	60% residential 40% commercial	(BSRIA, 2014)
Hours of use	Annual operating hours of ACs	5.6 hr/day residential 8hr/day commercial	(MEMR, 2015a) and LBNL assumption

Table 7. Estimated Annual UEC by EL for 0.75-RT (9,000-Btu/hr) ACs

EL	Definition	ISO CSPF	UEC*
		Btu/hr/W	kWh/yr
EL0	Indonesia MEPS 2020 (ASEAN SHINE)	10.57	780
EL1	Indonesia 4-star (2018)	11.05	758
EL2	20% above Indonesia MEPS (2020)	12.68	688
EL3	Singapore 2020	15.43	582
EL4	Potential China MEPS (2022)	20.79	419
EL5	China Grade 1 (2020)	24.96	333
EL6	U4E High Efficiency	27.46	298
EL7	BAT	30.61	271

*We calculate UECs in accordance with the ISO 16538 method based on AC use of 1,817 hr/yr, adjusted to hours of use in Indonesia of 5.6 hr/day for the residential sector and assuming 8 hr/day for the commercial sector.

As shown in Table 7, EL 4, which represents China's 2022 MEPS, results in 46% less annual energy use than the 2022 levels recommended by ASEAN SHINE (EL0), and 45% less annual energy use than Indonesia's 4-star standard in 2018 (EL1). EL7, which represents the BAT, would result in 64% less annual energy consumption when compared with ASEAN SHINE 2020 (EL1).

6 Engineering Analysis

The engineering analysis establishes the relationship between AC manufacturing cost and efficiency, which is used to calculate costs and benefits at the consumer, manufacturer, and national levels. The engineering analysis estimates the costs of efficiency improvement by assessing the energy performance of various higher-efficiency AC configurations and their associated incremental costs.

6.1 Methods

In this section, we describe the analytical framework followed, and the technologies considered to improve the efficiency of room AC systems. Shah et al. (2015) and Karali et al. (2019) considered various combinations of efficient technologies used in higher efficiency room ACs to estimate the total incremental cost and financial benefits of efficiency improvement to the room AC owners in India and China, respectively. Their methodology is similar to those used in the U.S. and EU MEPS rulemaking process to estimate the incremental cost of efficiency improvement of appliances. The method shows the economic costs and efficiency ratings of different combinations of efficient technologies on a cost curve. This analysis follows the same approach to calculate the cost and benefits gained from using more efficient technologies in a room AC system.

The total incremental manufacturer production cost (MPC) of a design combination is calculated using the following equation:

$$\Delta MPC(m) = \sum_{i} cost_m(i)$$

And the incremental retail price (P) of the design combination *m* is calculated using the following equation:

$$\Delta P(m) = \Delta MPC(m) * markup$$

Where:
$cost_m(i)$ = the incremental cost of component *i* used in design combination *m* compared to the baseline component.
Markup = the markup rate from manufacturing cost to user price, including manufacturer markup (MM) and distributor markup (DM). Retail price data from the IDEA database and manufacturer inputs are used to calibrate markup rates and validate the analysis results.

The overall percentage savings of the design combination m, $total\ energy\ saving(m)$, compared to the baseline model, is calculated as follows:

$$total\ energy\ saving(m) = 1 - \prod_i (1 - energy\ saving_m(i))$$

Where:
$energy\ saving_m(i)$ = the percentage energy savings gained from component i used in the design combination m compared to the baseline component.

The efficiency rating (in CSPF) of the corresponding capacity and type of the design combination m is calculated as follows:

$$efficiency\ rating(m) = \frac{capacity}{power\ input * (1 - \ total\ energy\ saving(m))}$$

Where:
$capacity$ = cooling capacity.
$power\ input$ = the power requirement of the baseline room AC.

In addition, the model provides the option of disaggregating the MPC into four categories: labor costs, material costs, factory overhead, and depreciation. This option allows use of default material weights, labor hours, and material costs adapted to Indonesia when MPC data are not directly available from interviews with manufacturers.

The representative 0.75-RT mini-split room AC used in this study is a fixed speed drive (FSD) room AC with a CSPF 10.5 (Btu/hr/W) rating and a MPC of US$ 102 (~1,440 thousand Rp).[12] Manufacturing costs of baseline components are based on an LBNL study estimating the economic benefits and costs of higher-efficiency mini-split room ACs to identify cost-effective AC energy-efficiency improvements in China (Karali et al., 2019).[13] Because China manufactures over 70% of room ACs in the global market (Shah et al., 2017), Chinese cost data provide a reasonable proxy for baseline component costs. Figure 9 shows the share of component costs for the representative baseline unit.

[12] 1 Indonesian Rupiah (Rp.) = 0.000071 US$ (as in 2 December 2019)

[13] Fixed speed compressor in a standard air conditioner (FSD) runs at 100% capacity when it is started, compared to a variable speed drive (VSD), i.e., inverter, room AC, which starts at a low level and then progressively enhances its capacity, in the proportion to the difference between set temperature and actual room temperature. This is why inverter systems are more efficient than fixed speed systems, also in regions with relatively constant ambient temperatures around the year like Indonesia.

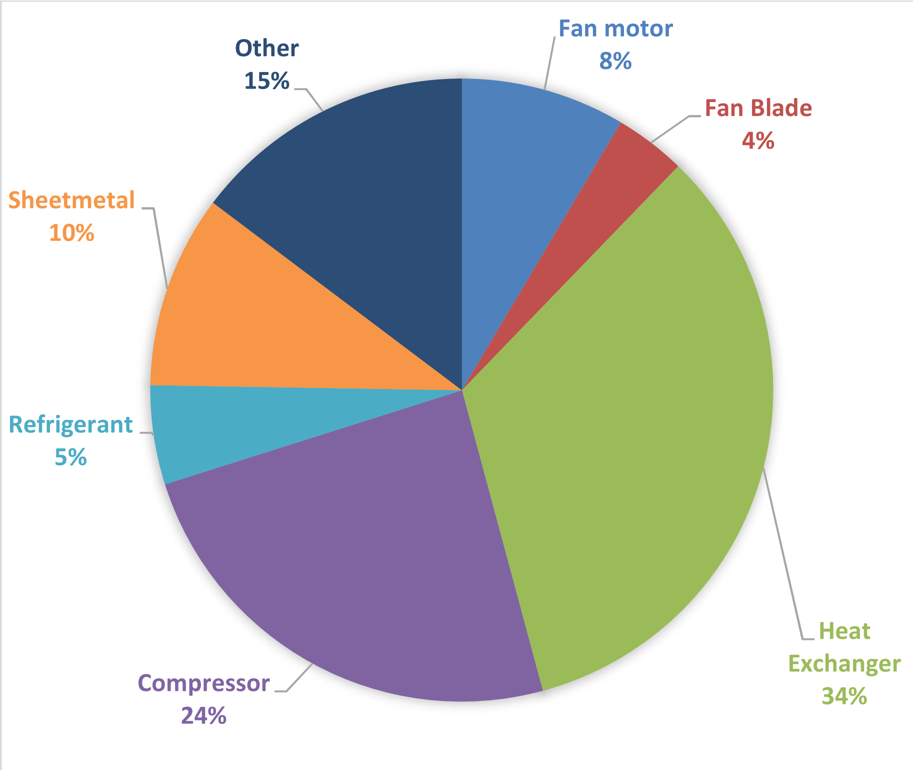


Figure 9. Estimated baseline manufacturing cost shares by component for 0.75-RT mini-split room AC in Indonesia, excluding markups (Karali et al., 2019)

Table 8 shows the energy savings and cost of each efficiency component used in this analysis. Four categories of technologies, both in the market and under development, can be used to improve mini-split AC efficiencies: compressors, variable-speed drives (VSDs), heat exchangers, and expansion valves. We develop a total of 306 AC designs by combining these technologies, resulting in a price-versus-efficiency curve based on the lowest-cost design combinations for given ELs. The simulated performance of the efficient technologies used in this study were verified via actual performance data in Riviere et al. (2009). The incremental manufacturing cost estimates of more efficient technologies were developed using market research and interviews with appliance and component manufacturers and experts in Indonesia.

In addition, purchase prices of ACs in local markets are based on retail price data from the IDEA database, which are obtained through web and retailer surveys, manufacturer websites, and government registration data (Letschert et al., 2017).

Table 8. Incremental Costs and Energy Savings Considered for 0.75-RT Mini-split Room AC Components

	Component	Incremental cost % *	Energy Savings from Baseline
Compressor**			
Compressor 1	3.0 EER Compressor	7%	4.8%
Compressor 2	3.2 EER Compressor	10%	9.8%
Compressor 3	3.4 EER Compressor	20%	15.0%
Compressor 4	3.6 EER Compressor	50%	20.0%
VSD, i.e., inverter***			
InverterAC	AC compressor with VSD	119%	22.8%
Inverter DC	DC compressor with VSD	162%	24.8%
Inverter and fanDC	DC fans and compressor with VSD	217%	27.5%
Heat Exchanger (HE)			
HE 1	UA of both HEs increases by 20%	20%	6.8%
HE 2	UA of both HEs increases by 40%	40%	12.8%
HE 3	UA of both HEs increases by 60%	60%	16.5%
HE 4	UA of both HEs increases by 80%	90%	19.5%
HE 5	UA of both HEs increases by 100%	120%	22.5%
Valve			
TXV	Thermostatic expansion valve	33%	5.0%
EXV	Electronic expansion valve	230%	9.0%

*Source: Manufacturer inputs

**The baseline compressor has a 2.9 EER rating. UA represents the product of overall heat exchange coefficient (U) and heat exchanger area (A).

***Incremental costs of VSD options are defined compared to the cost of baseline compressor with FSD.

6.2 Summary of Inputs

Table 9 lists the key data inputs for the engineering analysis.

Table 9. Key Data Inputs for Engineering Analysis

Input	Description	Value	Source
Component costs	Includes labor costs, material costs, factory overhead, and depreciation	Table 8	LBNL estimates
MPC	Sum of all component costs, including labor costs, material costs, factory overhead, and depreciation	Baseline US$102	Calculation
Manufacturer selling price (MSP)	MPC × (1+ MM)	Baseline US$138	Calculation
Retail price (P)	MPC × (1 + MM + DM)	Baseline US$194	Calculation
MM	Covers per-unit research and development expenses; selling, general, and administrative expenses; interest; and profit	35%	Manufacturer interviews
DM	Represents the markups in distribution channels	55% (includes 10% VAT)	Manufacturer interviews and (Indonesia Investments, n.d.)

Note: Installation costs are assumed to be the same for baseline and more efficient units - so the incremental installation cost is 0.

6.3 Results

Figure 10 provides the cost breakdown for the baseline 0.75-RT mini-split room AC. The total retail price is broken down by MPC (80% of which is material cost, 12% labor, and 8% depreciation and overhead), MM (35% of MPC), and DM (55% of MPC).

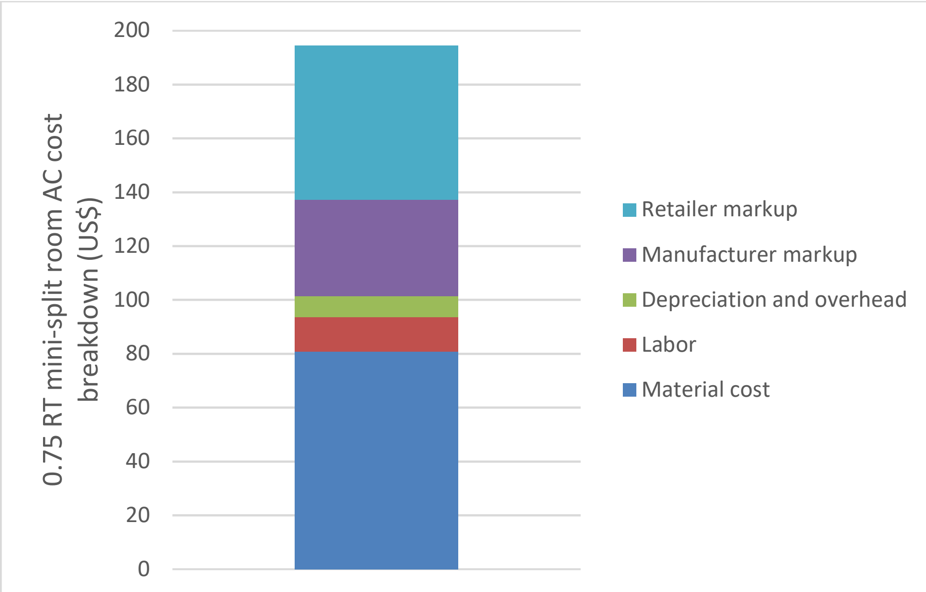


Figure 10. Cost breakdown for baseline 0.75-RT mini-split room AC

Figure 11 shows the manufacturing costs and retail prices of efficiency improvement for 0.75-RT ACs based on our analysis. The figure also presents actual retail prices of fixed- and variable-speed room ACs in the Indonesian market to validate our price predictions based on a 90% total markup rate. Current market prices appear to show bundling of AC features other than efficiency, because prices often vary substantially among products with similar efficiencies. When considering only the actual costs of components, the incremental costs of higher efficiency are low (Table 7). Super-efficient levels that are not yet available on the Indonesian market can be reached with more significant price increases. Efficiency-related price increases are expected to decline as the market achieves economies of scale (Taylor et al., 2015), such as when China revises its MEPS. Furthermore, although Figure 10 and subsequent analysis show higher efficiency increasing prices—which is typically the case in a market at any single point in time—analyses that account for evolution over time across multiple markets and multiple appliances show that prices of more efficient appliances tend to fall over time while efficiency keeps improving (Abhyankar, Shah, Park, et al., 2017; Spurlock et al., 2013).

Although the results in this section focus primarily on 0.75-RT room ACs, the trends discussed are likely to be the same for ACs with other capacities.

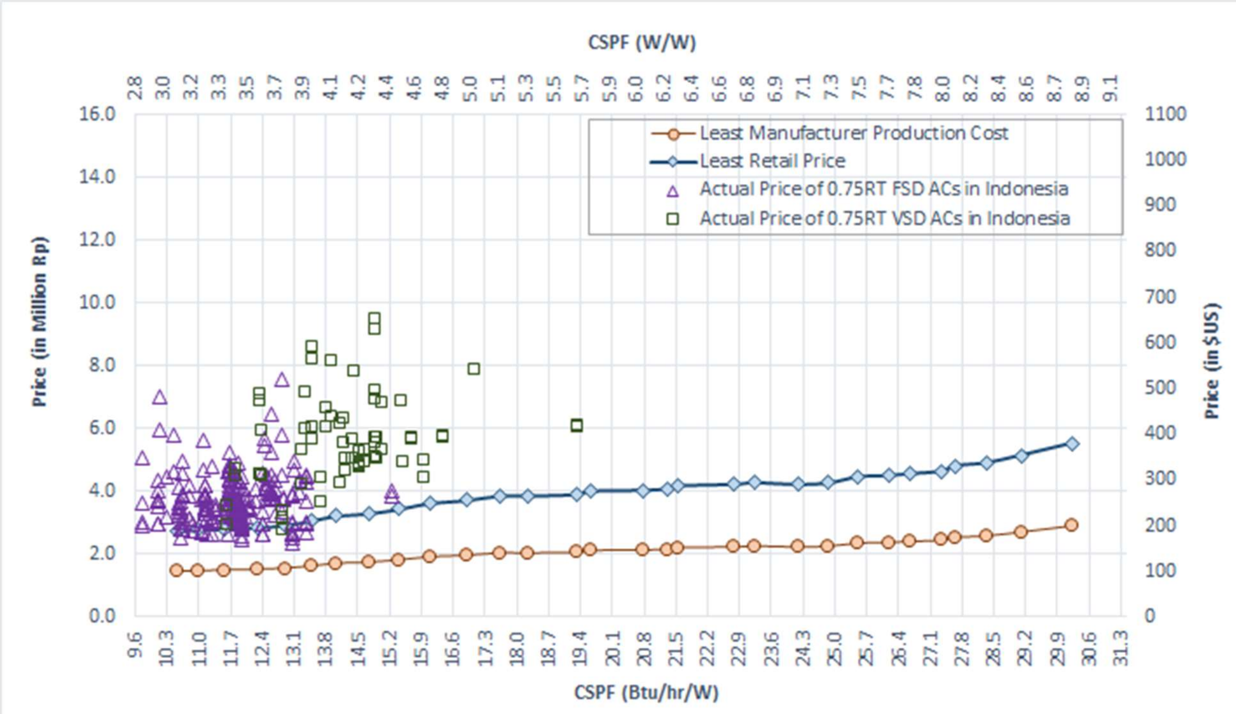


Figure 11. MPC and retail price vs. efficiency estimates for 0.75-RT mini-split room ACs in Indonesia compared with actual prices

We use the ELs defined in Table 5 to calculate the retail price of ACs based on the price-versus-efficiency curve in Figure 11. We then convert the EERs from the IDEA model database (Letschert et al., 2017) to calculate the current mix of ELs in the market in CSPF-equivalent. By applying these market shares to efficiencies and UECs from Table 7, and to the retail prices given by Figure 11, we calculate average market-weighted CSPF efficiency, UEC, and price under BAU and higher-MEPS scenarios (Table 10). In the BAU scenario, we assume that the current market shares by EL remain the same in the future. In each higher-MEPS scenario, all models that do not comply with the MEPS "roll up" to the MEPS level.

Table 10. Estimated Market Penetration of ACs at Various ELs and Market-Average Efficiency, Price, and UEC under BAU and Higher-MEPS Scenarios

		Scenario							
	EL	BAU	MEPS at EL1	MEPS at EL2	MEPS at EL3	MEPS at EL4	MEPS at EL5	MEPS at EL6	MEPS at EL7
Percentage of All Market ACs at Given EL	EL0	21%							
	EL1	44%	65%						
	EL2	20%	20%	85%					
	EL3	15%	15%	15%	100%				
	EL4	0%	0%	0%	0%	100%			
	EL5	0%	0%	0%	0%	0%	100%		
	EL6	0%	0%	0%	0%	0%	0%	100%	
	EL7	0%	0%	0%	0%	0%	0%	0%	100%
Market-Average CSPF Efficiency (Btu/hr/W)		11.94	12.03	13.09	15.43	20.79	24.96	27.46	30.61
Average Price (US$)		$219	$219	$226	$259	$304	$328	$342	$399
Average UEC (kWh/year)		722	718	672	582	419	333	298	271

7 Life-Cycle Cost Analysis

Implementation of efficient technologies generally increases production costs, which are passed on to the user in the form of higher retail prices. The LCC calculation analyzes the tradeoff between these increased first costs and subsequent savings in the form of lower utility bills. Our LCC analysis scales future energy cost savings by an appropriate discount factor to account for user preference for immediate over deferred gains. The analysis is implemented using the Policy Analysis Modeling System (PAMS), a tool developed by LBNL to analyze costs and benefits of AC MEPS under different efficiency scenarios. The tool allows us to continually refine the analysis as more data become available.

7.1 Methods and Data Inputs

The LCC of any appliance or other energy-consuming equipment accounts for all expenditures associated with the equipment's purchase and use. From the user perspective, the two main components of the LCC are the equipment cost (first cost) and the operating cost. Equipment cost is the retail price paid by the user purchasing the appliance. Operating cost is the cost of energy, in the form of utility bills, for using the equipment. LCC is given by:

$$LCC = PP + \sum_{n=1}^{L} \frac{OC}{(1+DR)^n}$$

Where:
PP = purchase price.
n = year since purchase.
OC = annual operating cost.
Operating cost is summed over each year of the lifetime of the appliance, L. Operating cost is calculated by multiplying the UEC (in kWh, from Table 7) by the price of electricity (P, in dollars per kWh) as follows:

$$OC = UEC \times P$$

The price of electricity (P) is taken from the tariff structure issued by MEMR (MEMR, 2016, 2017b). The tariff categories are divided by class of consumers. Mini-split ACs are found in both residential and light commercial applications. The residential electricity tariffs in Indonesia are split into three categories of consumers—R-1, R-2, and R-3—all of which require low-voltage (TR) electricity. Additionally, multiple tariff groups represent light commercial businesses. The B-2 tariff class is low voltage (TR), while the B-3 tariff class relies on medium-voltage (TM) electricity. The marginal price of electricity used in our analysis reflects the higher tariff blocks for the residential and light commercial customers with a price of 1,467.28 Rp/kWh or US$0.105/kWh.

The fact that future costs are less important to users than near-term costs is taken into account by dividing future operating costs by a discount factor $(1+DR)^n$, where DR is the discount rate. We derive the discount rates for the LCC analysis from estimates of the finance cost for purchasing the products studied. Following financial theory, the finance cost of raising funds to purchase equipment can be interpreted as: (1) the financial cost of any debt incurred to purchase equipment, or (2) the opportunity cost of any equity used to purchase equipment. We define the discount rate as the average Indonesian rate of lending, as estimated by the World Bank (The World Bank, 2019).

The method used for conducting the LCC and payback period analyses is depicted in Figure 12.

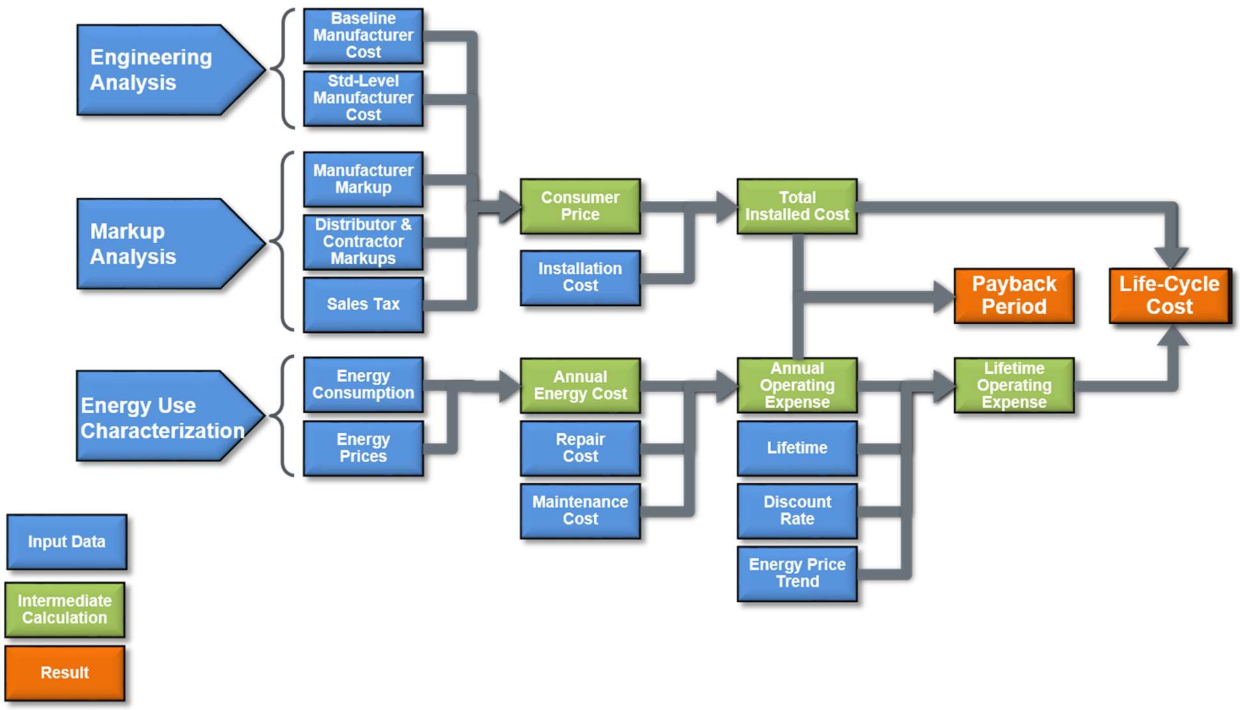


Figure 12. Method flowchart: LCC and payback period analysis

7.2 Summary of Inputs

Table 11 summarizes the key data inputs for the LCC analysis.

Table 11. Key Data Inputs for LCC Analysis

Input	Description	Value	Source
UEC	Representative unit's average annual energy consumption for different ELs	Table 7	Energy-use analysis
Purchase price (PP)	Representative unit's average purchase price for different ELs	Table 10	Engineering analysis
Lifetime (L)	Average lifetime	8 years	Authors' estimate
Discount rate (DR)	Average lending rate	12.6%	(The World Bank, 2019)
Electricity price (P)	Marginal price of electricity	$0.105/kWh	(MEMR, 2016, 2017b)

7.3 Results

Table 12 presents the results for the representative AC unit under different efficiency scenarios. Given the large amount of energy consumed by ACs, operating costs represent a very large portion of overall LCC. Therefore, even with a high user discount rate, all higher-efficiency policies are very cost-effective to the consumer, with LCC savings and payback periods of 1.4–3.8 years (relative to an 8-year lifetime). The technical potential afforded by high efficiency ACs is also the cost-effective potential. Maximum consumer benefits are found with MEPS at CSPF = 27.46.

Table 12. LCC and Payback Period Results for the Representative AC Unit

EL	Market-Weighted CSPF	LCC				LCC Savings	Payback Period
		Average Purchase Price	UEC	Average Annual Electricity Bill	Average LCC		
	Btu/hr/W	$	kWh/yr	$	$	$	years
BAU	11.94	$219	722	$76	$587		
MEPS at CSPF = 11.05	12.03	$219	718	$75	$585	$2	1.4
MEPS at CSPF = 12.68	13.09	$226	672	$70	$569	$18	1.4
MEPS at CSPF = 15.43	15.43	$259	582	$61	$555	$32	2.7
MEPS at CSPF = 20.79	20.79	$304	419	$44	$518	$69	2.7
MEPS at CSPF = 24.96	24.96	$328	333	$35	$498	$89	2.7
MEPS at CSPF = 27.46	27.46	$342	298	$31	$493	$94	2.8
MEPS at CSPF = 30.61	30.61	$399	271	$28	$537	$50	3.8

8 National Impact Analysis

Policymakers consider not only financial impacts on individual users, but also the magnitude of efficiency impacts on the nation as a whole, which is where the sales and stock of ACs are taken into account. We calculate national impacts using PAMS.

8.1 Methods and Data Inputs

There are two main calculations for MEPS impact at the national level: national energy savings (NES) and net present value (NPV). NES is the total primary (input) fossil-fuel energy saved in the policy scenario versus the BAU scenario over the 2021–2035 forecast period. NPV is the discounted net benefit of financial savings to the entire market of users.

In some sense, national impacts are a scaling up of unit-level impacts to cover the whole market. National impacts also introduce an important time component to the evaluation of program impacts. MEPS generally affect new products only, and they usually do not affect products already installed before the MEPS implementation date. Therefore, in the first year after standards are implemented, savings are usually small, because the standard only affects products purchased in that year. As time goes on, more and more of the stock is made up of products purchased after standards took effect and thus reflecting the MEPS level. The national impacts calculations describe the evolution of the stock and provide a profile of costs and benefits over time.

8.1.1 Stock Forecast

To determine the national-level impacts of MEPS, we forecast the total number of products operating in Indonesia in each year and the rate at which old, inefficient products are replaced with new, efficient ones. Therefore, product sales (shipments) and stock forecasting are major components of the national impacts model.

Both population growth and trends in appliance ownership rates drive the national end-use consumption and appliance stock. In developing countries, ownership rates of even basic appliances are dynamic and heavily dependent on household income level, degree of urbanization, and electrification rates; countries experiencing rapid growth in those areas see dramatic growth in appliance ownership (McNeil et al., 2007a). Given this relationship, the PAMS model bases projections of end-use consumption and subsequent savings from efficiency programs on a model relating ownership response to those three areas. In order to arrive at the national ownership rate for each year in the forecast, the PAMS model combines population forecasts with an income model and econometric parameterization.

Figure 13 presents the results of the macro-economic model from PAMS.

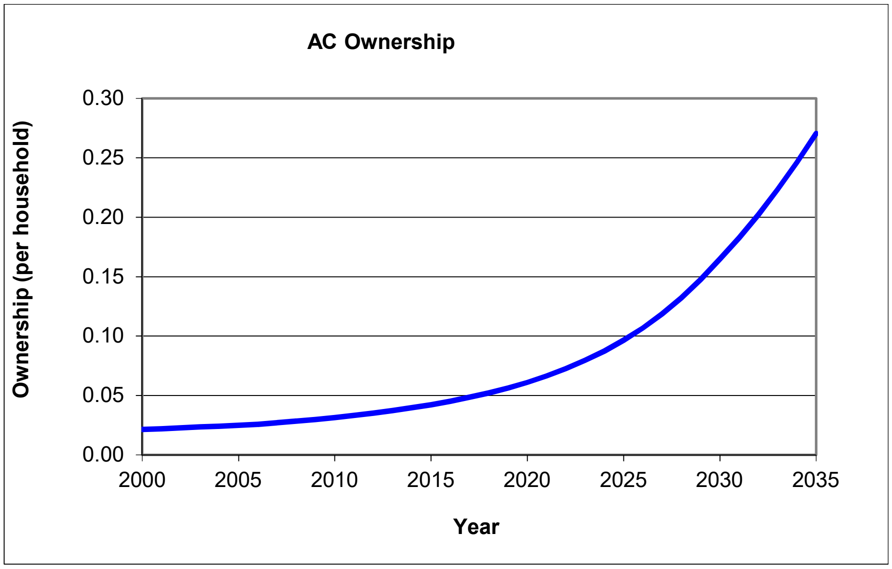


Figure 13. Indonesia AC ownership 2000–2035

Sales are driven by the increase in stock of ACs and by the replacement of retired ACs:

$$Sales(y) = FP(y) + Rep(y)$$

Where:
FP(y) = first purchase in year y
Rep(y) = replacement in year y

The stock is calculated using the PAMS macroeconomic model. The PAMS model is used to calculate the 2015–2035 growth rate (McNeil et al., 2007b, 2007a). In this case, FP is given by:

$$FP(y) = Stock(y) - Stock(y-1)$$

Where:
Stock(y) = number of units in operation in the country in year y
Stock(y-1) = number of units in operation in the country in year y-1

In addition to first purchases, we calculate the replacement of ACs in terms of an annual retirement probability that varies as a function of the AC age, given by:

$$P_{R(age)} = \frac{1}{1 + e^{(age-L)/D_{age}}}$$

Where:
$P_{R(age)}$ = probability of retirement at a given product age.
L = average lifetime of the product.
D_{age} = mean deviation of replacement ages, assumed to be 2 years.

Finally, replacements in each year are given by the relationship:

$$Rep(y) = \sum_{age=1}^{2L} Stock(y-1, age) \times P_{R(age)}$$

Applying this method, we find an annual growth rate of 7.5%. This growth rate is then applied to the Euromonitor data as described in Section 4.

8.1.2 National Energy Savings Calculation

NES is defined as the difference in energy consumption between the BAU scenario and the policy scenario. In the BAU scenario, all products are assumed to be operating at the baseline efficiency. In the policy scenario, products purchased after the standards program implementation date (a user-adjustable parameter) are assumed to operate at the efficiency determined by a specific design option combination chosen by the model user.

PAMS calculates NES in each year by comparing the national energy consumption of the product under study in the BAU scenario and the policy scenario, according to:

$$NES = NEC_{BAU} - NEC_{Policy}$$

In turn, the national energy consumption (NEC) of the national stock of products in year y is given by:

$$\mathrm{NEC_{BAU}} = \sum_{\mathrm{age}} \mathrm{Stock\ (y)} \times \mathrm{UEC_{BAU}(y - age)}$$

Where the UEC is determined according to the year of purchase (y-age). The UEC differs between the BAU and policy scenario for years after the MEPS implementation date because of the improvement in efficiency resulting from the standards, according to the following relationship:

$$UEC = UEC_{BAU} \times Efficiency_{BAU}/Efficiency_{Policy}$$

Finally, CO_2 emissions savings (CES) are calculated from energy savings by applying carbon factors to site energy savings according to:

$$CES = \frac{NES}{1-TD} \times CaF$$

Where:

TD = the fraction of energy lost in electricity transmission and distribution.
CaF = the carbon factor derived from the fraction of fossil-fuel generation.

Figure 14 provides a flowchart of the inputs required to calculate NES.

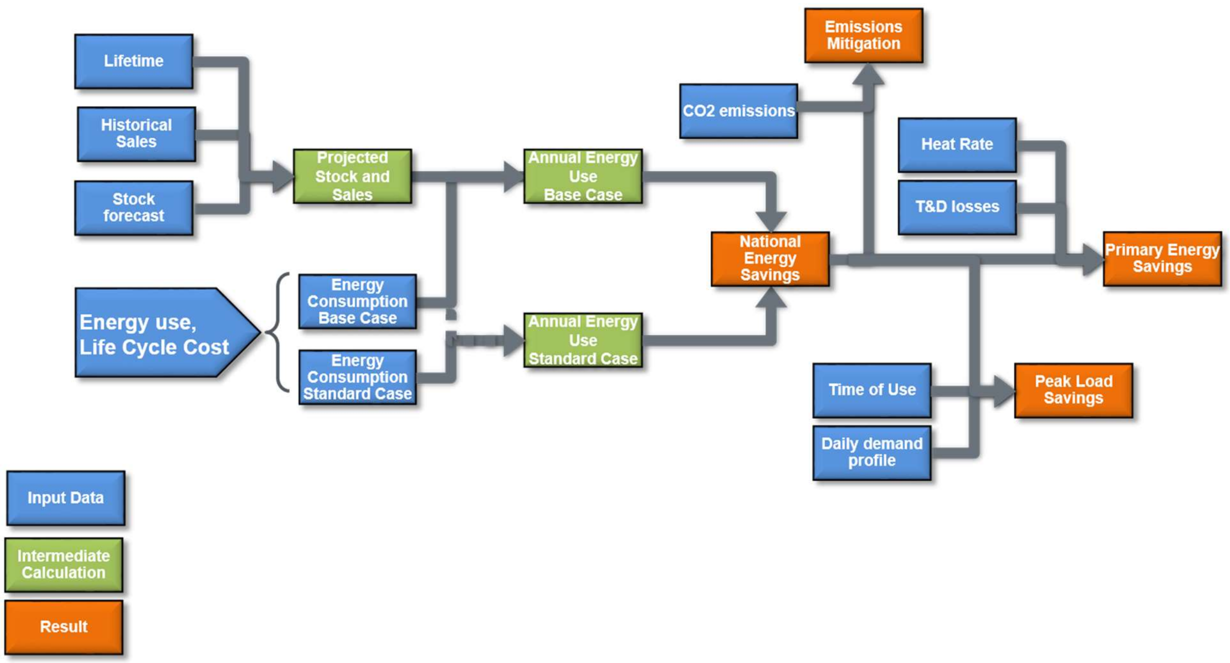


Figure 14. Method flowchart: NES and related metric calculation

8.1.3 Net Present Value Calculation

The NPV of a policy measures the policy's net financial benefit to the nation as a whole. As in the case of NES, the NPV calculation is somewhat parallel to the unit LCC calculation. National financial impacts in year y are the sum of equipment (first) costs and user operating costs. National equipment cost (NEqC) is equal to the retail price times the total number of sales:

$$NEqC = EC \times S(y)$$

Where:
EC = equipment cost (retail price).
S(y) = sales in a given year.

Likewise, national operating cost (NOC) is simply the total (site) energy consumption times the energy price:

$$NOC = NEC(y) \times P$$

The net savings in each year arise from the difference in first and operating costs in the MEPS scenarios versus the BAU scenario, ΔNEqC and ΔNOC. The NPV of the policy option is then defined as the sum over a particular forecast period of the net national savings in each year, multiplied by the appropriate national policy discount rate:

$$NPV = \sum_{y} (\Delta NOC(y) + \Delta NEC(y)) * (1 + DR_N)^{-(y-y_0)}$$

Where the subscript N indicates that, in general, the national policy discount rate will not be identical to the discount rate used in calculating LCC. For calculating NPV, y_0 is the current year, which may differ from the policy implementation year.

Figure 15 provides a flowchart of the inputs required to calculate NPV.

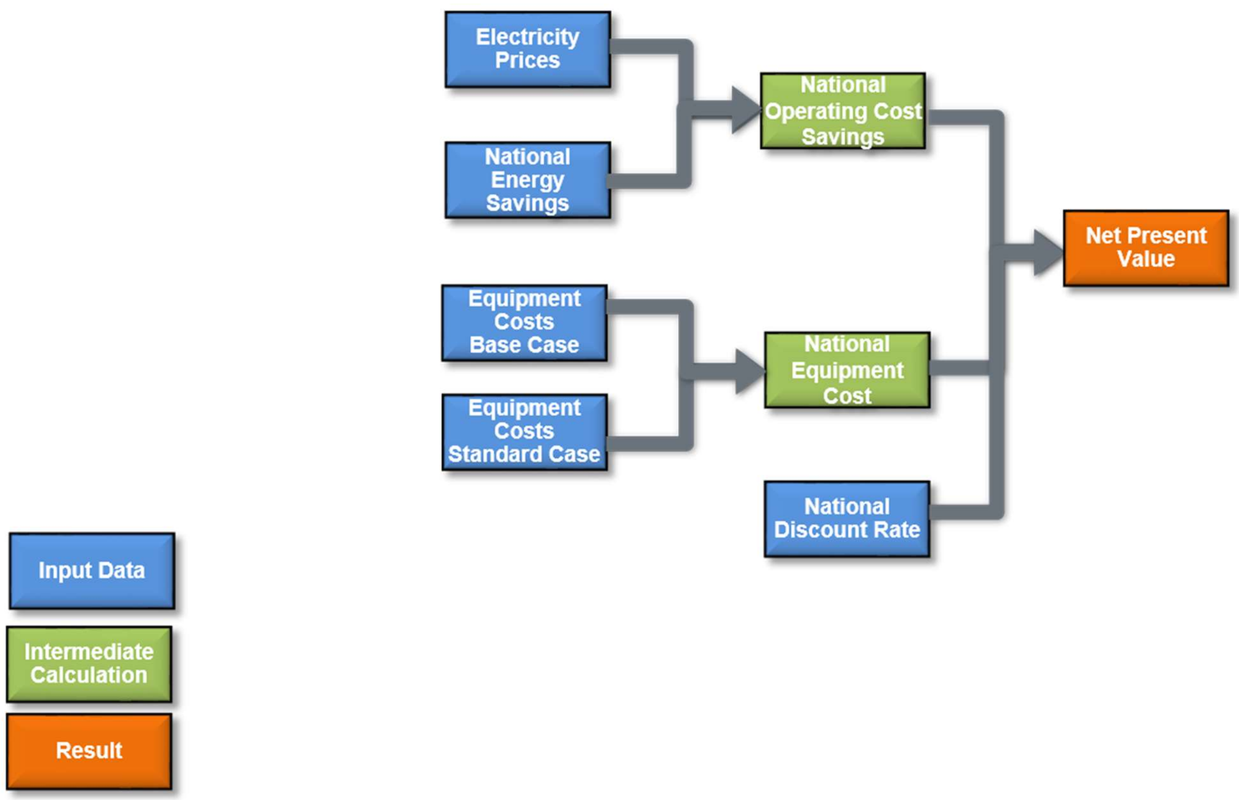


Figure 15. Method flowchart: NPV calculation

8.2 Summary of Inputs

Table 13 lists the key data inputs for the national impact analysis.

Table 13. Key Data Inputs for National Impact Analysis

Input	Description	Value	Source
Macroeconomic variables	Income, electrification, climate variable.	Times series	PAMS model
Sales data	Includes all sales of ACs that fall within MEPS scope	3,000,000 units in 2017	(Euromonitor International, 2017)
UEC at different ELs	UECs based on ACs being used 6.6 hr/day and in accordance with the ISO 16538 method	Table 7	Energy-use and LCC analyses
Costs at different ELs	Retail price estimates	Table 10	Engineering and LCC analyses
National policy discount rate (DR_N)	Based on the social discount rate applied to government projects	7.5%	(Global-Rates, 2019)
CO_2 emission factor	Electricity-specific emission factors	0.753 kg/kWh	(de la Rue du Can et al., 2015)
Transmission and distribution factor	Includes losses in transmission and distribution	9.4%	(The World Bank, 2019)

8.3 Results

The first result of the national impact analysis is the forecast of AC stock, based on sales inputs and average lifetimes. Figure 16 shows the total stock forecast for the representative AC unit.

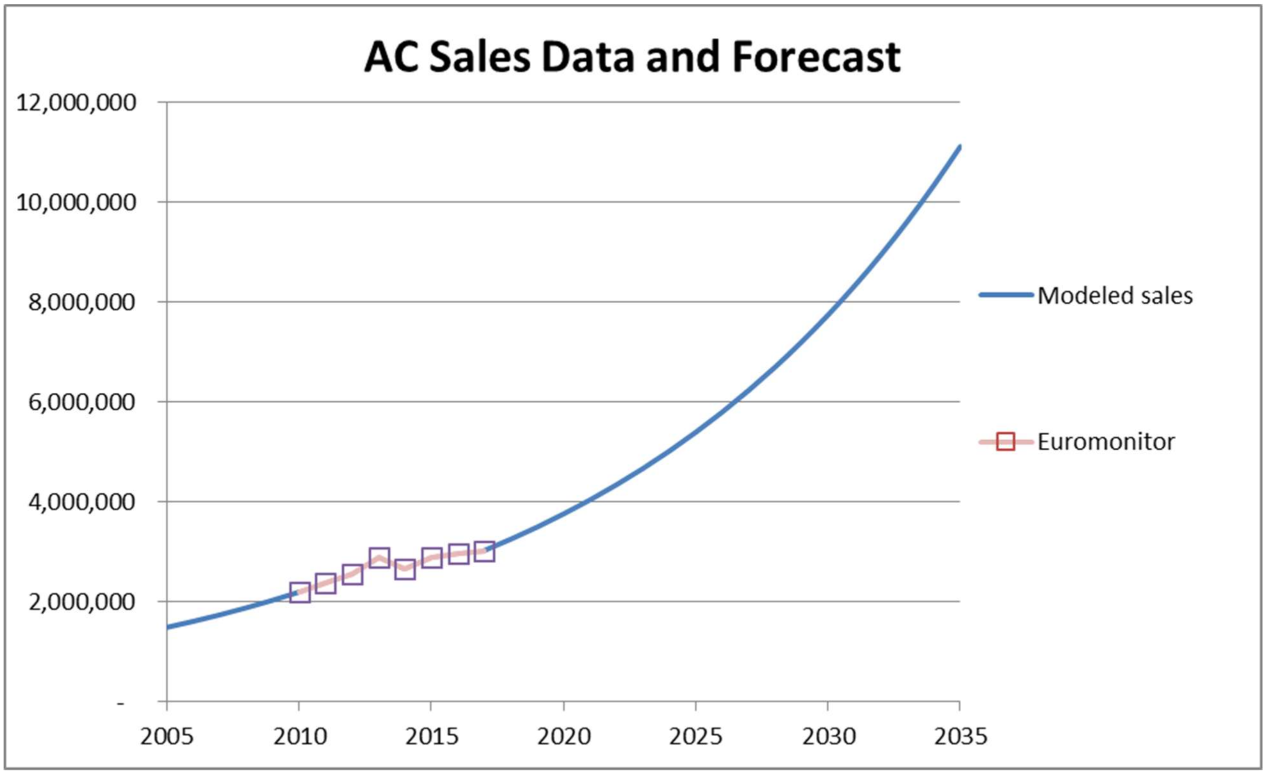


Figure 16. Indonesia AC sales forecast for the representative AC unit, from macroeconomic model

Figure 17 shows the national energy consumption of the representative AC unit in the stock, calculated using PAMS with direct inputs of sales and UECs.

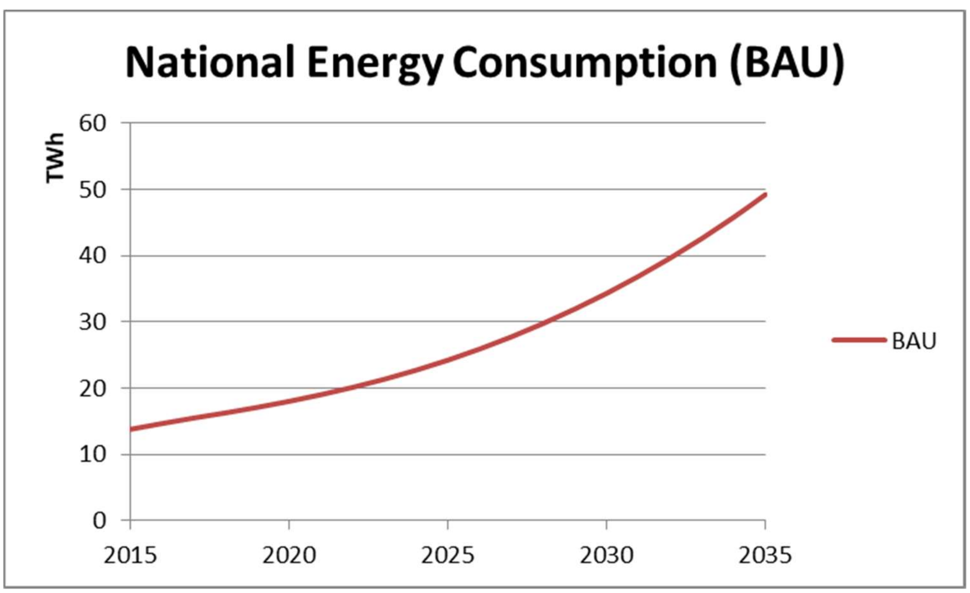


Figure 17. Indonesia national AC energy consumption forecast in BAU scenario, by representative AC unit

Table 14 through Table 18 present national results in the years 2025, 2030, and 2035 in terms of projected annual and cumulative energy savings, cumulative CO_2 emissions reductions, avoided capacity, and NPV. These preliminary results show that, in the MEPS at CSPF = 27.46 scenario (minimum LCC, maximum benefits to consumers), the NES would amount to 219 terawatt-hours (TWh) (site electricity) with a positive NPV of US$6.1 billion over the analysis period (2021–2035). At this EL, the cumulative CO_2 savings are 182 million metric tons through 2035, and the avoided capacity is 4,800 MW in 2035.

The technical potential that could be achieved from the most efficient technology, represented by the results for MEPS at CSPF = 30.61, shows that the cumulative NES would amount to 232 TWh (site electricity) with a positive NPV of US$3.9 billion over the analysis period (2021–2035). At this EL, the cumulative CO_2 savings are 193 million metric tons through 2035, and the avoided capacity is 5,100 MW in 2035.

Table 14. Annual NES for ACs under Different Efficiency-Level Scenarios in 2025, 2030, and 2035

Scenarios	Annual Energy Savings (GWh)		
	2025	**2030**	**2035**
MEPS at CSPF = 11.05	92	193	292
MEPS at CSPF = 12.68	1,032	2,162	3,263
MEPS at CSPF = 15.43	2,901	6,075	9,170
MEPS at CSPF = 20.79	6,276	13,144	19,840
MEPS at CSPF = 24.96	8,073	16,908	25,522
MEPS at CSPF = 27.46	8,803	18,437	27,829
MEPS at CSPF = 30.61	9,351	19,586	29,563

Table 15. Cumulative NES for ACs under Different Efficiency-Level Scenarios through 2025, 2030, and 2035

Scenarios	Cumulative Energy Savings (GWh)		
	2025	**2030**	**2035**
MEPS at CSPF = 11.05	268	1,036	2,294
MEPS at CSPF = 12.68	2,998	11,584	25,637
MEPS at CSPF = 15.43	8,427	32,557	72,053
MEPS at CSPF = 20.79	18,232	70,437	155,885
MEPS at CSPF = 24.96	23,453	90,608	200,527
MEPS at CSPF = 27.46	25,573	98,800	218,656
MEPS at CSPF = 30.61	27,167	104,957	232,283

Table 16. Cumulative CO_2 Emissions Mitigation for ACs under Different Efficiency-Level Scenarios through 2025, 2030, and 2035

Scenarios	Cumulative CO_2 Emissions Mitigation (million metric tons)		
	2025	**2030**	**2035**
MEPS at CSPF = 11.05	0	1	2
MEPS at CSPF = 12.68	2	10	21
MEPS at CSPF = 15.43	7	27	60
MEPS at CSPF = 20.79	15	59	130
MEPS at CSPF = 24.96	19	75	167
MEPS at CSPF = 27.46	21	82	182
MEPS at CSPF = 30.61	23	87	193

Table 17. Avoided Generation Capacity for ACs under Different Efficiency-Level Scenarios in 2025, 2030, and 2035

Scenarios	Avoided Generation Capacity (MW)		
	2025	2030	2035
MEPS at CSPF = 11.05	16	33	50
MEPS at CSPF = 12.68	178	373	563
MEPS at CSPF = 15.43	500	1,047	1,581
MEPS at CSPF = 20.79	1,082	2,266	3,421
MEPS at CSPF = 24.96	1,392	2,915	4,400
MEPS at CSPF = 27.46	1,518	3,179	4,798
MEPS at CSPF = 30.61	1,612	3,377	5,097

Table 18. NPV of Savings for ACs under Different Efficiency-Level Scenarios between 2021 and 2035

	MEPS at CSPF = 11.05	MEPS at CSPF = 12.68	MEPS at CSPF = 15.43	MEPS at CSPF = 20.79	MEPS at CSPF = 24.96	MEPS at CSPF = 27.46	MEPS at CSPF = 30.61
Total electricity savings (million US$)	132	1,472	4,136	8,949	11,512	12,552	13,335
Total incremental equipment cost (million US$)	35	374	2,089	4,483	5,744	6,442	9,459
NPV (million US$)	97	1,098	2,048	4,466	5,767	6,110	3,876

Figure 18 presents the national cost and benefits between 2021 and 2035 from the scenario with MEPS at CSPF = 27.46, which represent the maximum NPV valued at 6.1 Billion US$. The results are shown in terms of additional costs and additional economic savings, comparing the BAU scenario to the higher-MEPS scenario. In the higher-MEPS scenario, more expensive units replace less-efficient ones, which results in additional costs at the time of purchase and increased savings during the AC operating lifetime. When the energy cost reduction over the AC lifetime outweighs the non-energy (first) cost increase, the standards have a positive impact on users; otherwise, the standards' impact is negative. In this case, the standards have a net positive impact only 1 year after the standard takes effect.

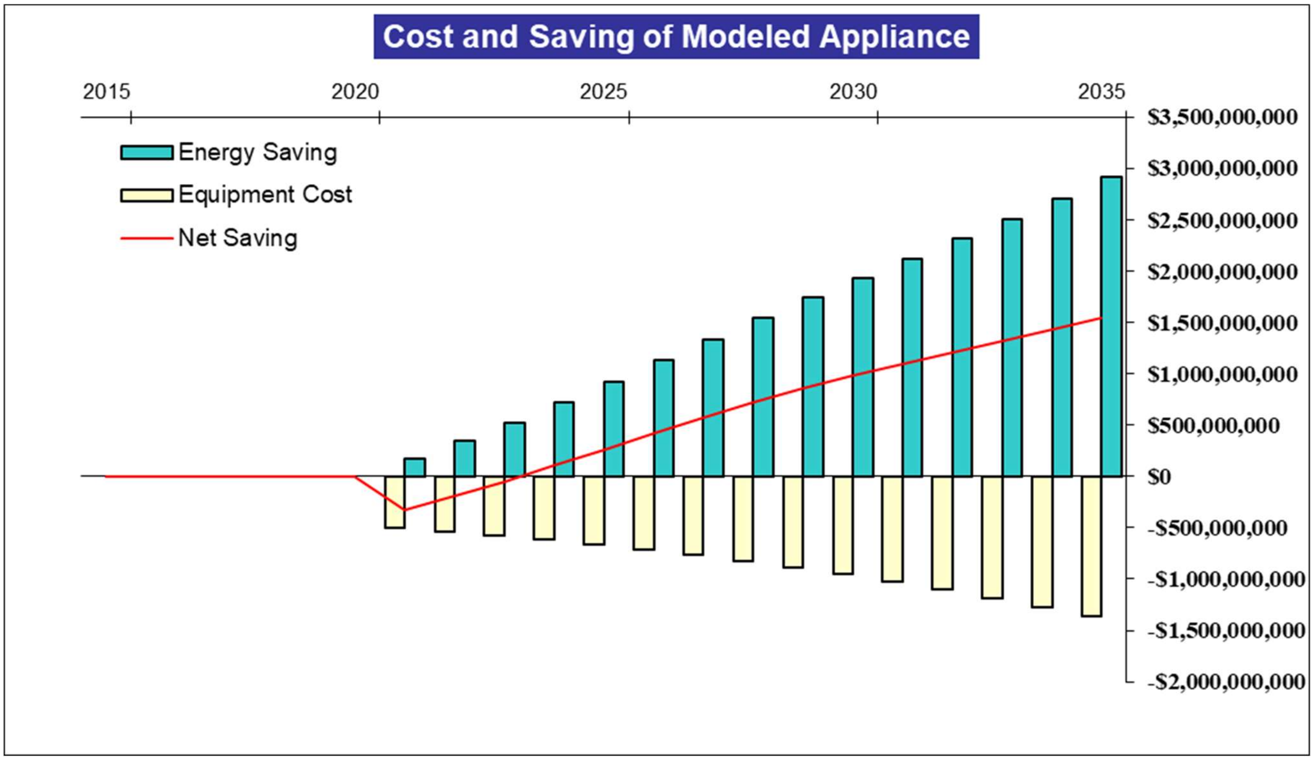


Figure 18. Cost and benefits of AC MEPS at CSPF = 27.46 (Maximum NPV for representative AC unit)

9 Manufacturer Impact Analysis

The manufacturer impact analysis estimates MEPS impacts on the industry manufacturing the AC equipment, to evaluate the impact of MEPS on local AC manufacturers in Indonesia. The analysis is based on a cash-flow model adapted for Indonesia and the AC industry, in the style of the analysis performed for U.S. appliance efficiency standards. The model evaluates how MEPS can impact local manufacturers in terms of investments, production costs per unit, and revenues resulting from changes in sales or prices. The key inputs to the model include information on industry cost structure, sales, and pricing strategies. The key output is the INPV in various policy scenarios. The model is populated with some default input data but have been customized to use the most reliable country-specific data inputs for more accurate results.

9.1 Methods and Data Inputs

This section presents inputs and intermediate calculations that feed into the INPV calculation.

9.1.1 Revenues

The manufacturer revenues represent the sum of MSPs associated with the sales in a specific year:

$$Revenues = \sum_{sales} MSP$$

9.1.2 Net Operating Profits after Taxes

One important input to the INPV calculation is the net operating profit after taxes (NOPAT).
The NOPAT is calculated as follows:

$$NOPAT = EBIT \ \times (1 - Tax\ rate)$$

Where earnings before interest and taxes (EBIT) are equal to:

$$EBIT = Revenues - \left(\frac{Revenues}{MM}\right) - Overheads - Equipment\ conversion\ costs$$

The overheads represent the selling, general, and administrative expenses as well as research and development expenses, which are taken from the engineering analysis. The equipment conversion costs represent one-time investments in research, product development, testing, certification, and marketing, which are non-capital investments that are needed after the standards are announced but before they take effect. These costs are equal to zero in the BAU scenario (absence of standards) and typically increase with MEPS stringency. For the AC industry, these costs are expected to be very low.

9.1.3 Free Cash Flow

Another intermediate calculation for the INPV determines free cash flow (FCF):

$$FCF = CF - Capital\ expenditures - Capital\ conversion\ costs$$

Where:

$$CF = NOPAT - Change\ in\ Working\ Capital$$

The model calculates the capital expenditures as a percentage of revenues using a default value that is customized for the Indonesian market. These capital expenditures represent the one-time expenses incurred for the purchase of plant, property, and equipment used in the production of ACs.

The capital conversion costs represent the one-time investments in plant, property, and equipment that result from establishing MEPS. The capital conversion costs are estimated based on manufacturer interviews.

9.1.4 Industry Net Present Values

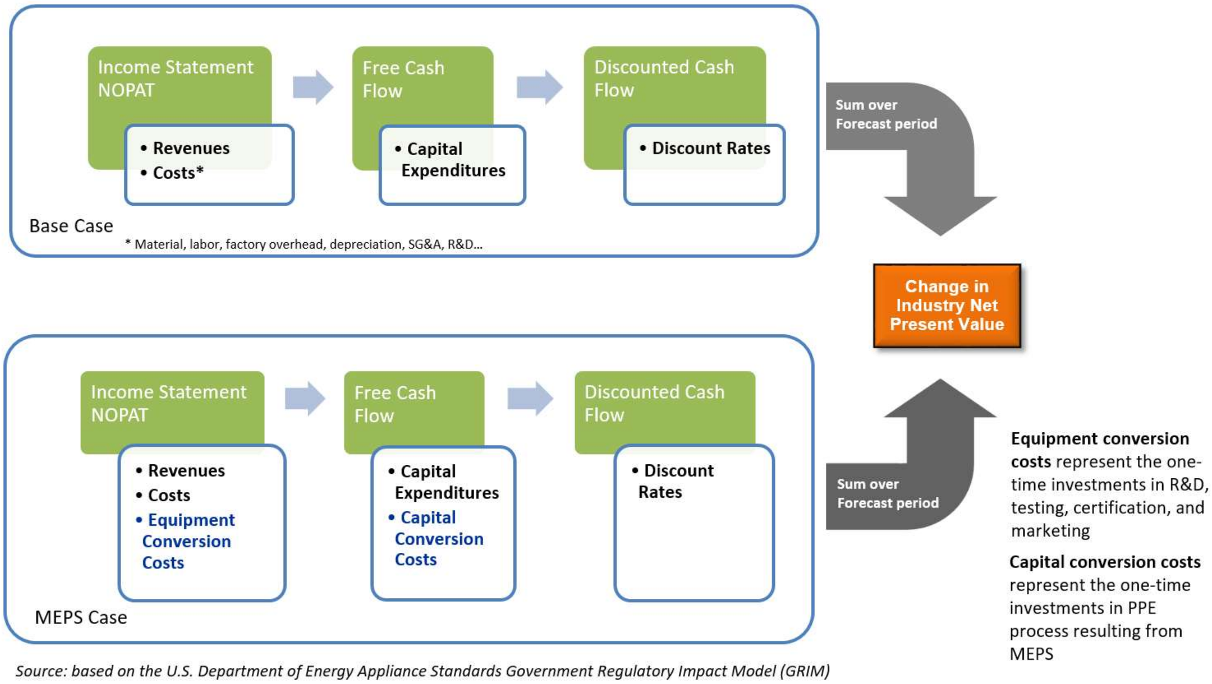
The INPV in the BAU scenario and in each MEPS scenario is calculated as:

$$INPV = FCF \times \left(\frac{1}{1 + Discount\ rate}\right)^{(yr - reference\quad)} + Terminal\ value$$

and:

$$Terminal\ value = FCF \times \frac{1 + Terminal\ growth\ rate}{Discount\ rate + Terminal\ growth\ rate}$$

Figure 19 shows the method and inputs required to conduct the manufacturer impact analysis.



PPE = plant, property, and equipment; R&D = research and development; SG&A = selling, general, and administrative.

Figure 19. Method flowchart: manufacturer impact analysis

9.2 Summary of Inputs

Table 19 summarizes the inputs to the manufacturer impact analysis.

Table 19. Key Data Inputs for Manufacturer Impact Analysis

Inputs	Description	Value	Source
Tax rate	Corporate effective income tax paid (percentage of earnings before taxes)	25%	(Indonesia Investments, n.d.)
Discount rate	Weighted average cost of capital	10.5%	waccexpert.com
Working capital	Current assets less current liabilities (percentage of revenues)	10%	(U.S. DOE, 2016)
SG&A	Selling, general, and administrative expenses (percentage of revenues)	13.8%	(U.S. DOE, 2016)
R&D	Research and development expenses (percentage of revenues)	2.3%	(U.S. DOE, 2016)
Capital expenditures	Cash expenditure to acquire or improve capital assets (percentage of revenues)	2%	(U.S. DOE, 2016)
Depreciation	Amortization of fixed assets (percentage of revenues)	2%	(U.S. DOE, 2016)
Equipment conversion costs	One-time investments in research and development, testing, certification, and marketing	Constant at all ELs, scales with	LBNL estimates

Capital conversion costs	One-time investments in plant, property, and equipment process resulting from the MEPS	production capacity	LBNL estimates
Stranded assets	Assets replaced before the end of their useful lives as a direct result of the MEPS		LBNL estimates

Note: this data was reviewed and confirmed during interviews with local manufacturers

9.3 Results

Table 20 presents manufacturer impact results under different MEPS scenarios compared to the BAU scenario.

Table 20. Manufacturer Impacts for ACs under Higher-MEPS (vs. BAU) Scenarios Through 2035

	MEPS at CSPF = 11.05	**MEPS at CSPF = 12.68**	**MEPS at CSPF = 15.43**	**MEPS at CSPF = 20.79**	**MEPS at CSPF = 24.96**	**MEPS at CSPF = 27.46**	**MEPS at CSPF = 30.61**
Product Conversion Cost (million US$)	0.4	1.1	1.5	1.7	1.7	1.7	2.1
Capital Conversion Cost (million US$)	0.7	0.9	1.7	2.1	2.1	2.1	3.9
Total Investment Required (million US$)	1.1	2.0	3.1	3.9	3.9	3.9	22.4
Change in INPV (million US$)	0.9	1.4	6.9	15.1	19.8	22.4	33.7

While manufacturers see a benefit under all scenarios, the change in INPV is highly positive and increasing for MEPS set at CSPF = 15.43 and above, indicating that manufacturers will benefit most by switching their production to high-efficiency variable-speed ACs. Modest incremental improvements in efficiency imply similar investment costs that manufacturers may not recover in their future revenues.

Figure 20 presents the annual FCF from 2018 through 2035 for the BAU and higher-MEPS scenarios. It is important to note the short-term changes in cash flow in the years preceding the regulation (which is implemented in 2021). In the higher-MEPS scenarios, investments in conversion costs increase between the announcement date and the date of compliance (2018–2021) to prepare for the new regulation. As a result of these investments, industry cash flow declines during those years (as revenue increase is only driven by sales). In the years after the standards (2021–2035), revenues and hence cash flow increase compared to the BAU scenario owing to the higher price of more efficient ACs.

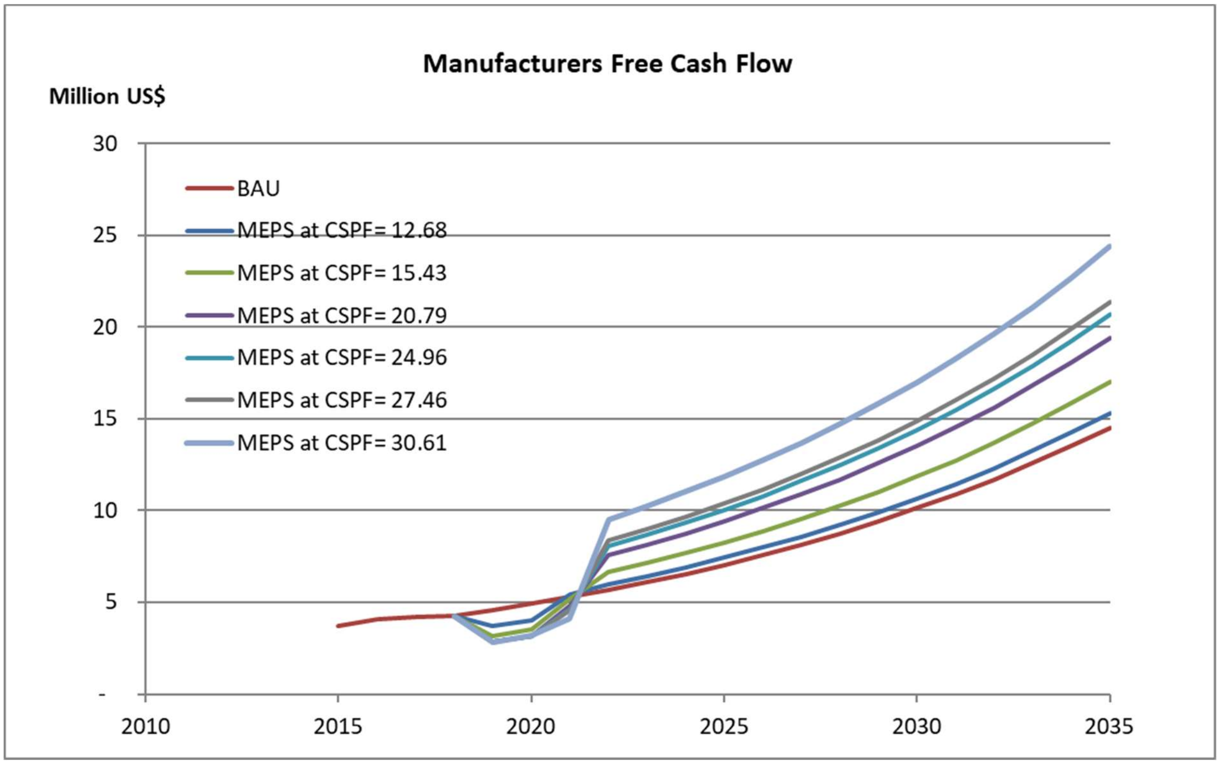


Figure 20. Indonesian AC manufacturer FCF under BAU and higher-MEPS scenarios (with specified MEPS effective in 2021)

10 Recommendations on MEPS and Labeling Program

As neighboring countries and China revise their MEPS upward and the U4E Model Regulation Guidance gets broadly disseminated in ASEAN and beyond, Indonesia cannot prevent the dumping of inefficient ACs from these markets without a more ambitious and re-scaled standards-and-label strategy. By revising the MEPS, Indonesia can capitalize on the opportunity to capture both economies of scale and lower costs for more efficient ACs, and increase its competitiveness in the regional market.

Our analysis suggests immediate rescaling of Indonesia's AC S&L program should be considered at the levels shown in Table 21, with longer-term levels as shown in Table 22 to align with ASEAN, China and other international markets.

Table 21. Proposed Indonesia AC MEPS and Labels (2021)

Star Level	Efficiency in CSPF (Btu/hr/W)	Equivalent
1 Star (MEPS)	12.68	20% above Indonesia MEPS (2020)
2 Star	15.43	Singapore (2020)
3 Star	20.79	Potential China MEPS (2022)
4 Star	24.96	China Grade 1 (2020)
5 Star	27.46	U4E High Efficiency

Table 22. Proposed Indonesia AC MEPS and Labels (2023)

Star Level	Efficiency in CSPF (Btu/hr/W)	Equivalent
2 Star	15.43	Singapore 2020
3 Star	20.79	Potential China MEPS (2022)
4 Star	24.96	China Grade 1 (2020)
5 Star	27.46	U4E High Efficiency

Specifically our analysis has shown that higher MEPS result in substantial national energy savings, CO_2 emission reductions, avoided generation, national financial benefits, while providing some increased revenues opportunities to local manufacturers. Table 23 presents the summary results in/through 2035 for the MEPS and Label levels presented above.

Table 23. Consumer, National and Manufacturer Impacts Summary scenarios (with specified MEPS effective in 2021)

	MEPS* at CSPF= 12.68	MEPS at CSPF= 15.43	MEPS at CSPF= 20.79	MEPS at CSPF= 24.96	MEPS at CSPF= 27.46
Equivalent to:	**Revised ASEAN target 1 Star**	**Singapore (2020) 2 Star**	**Potential China MEPS (2022) 3 Star**	**China Grade 1 (2020) 4 Star**	**U4E High Efficiency 5 Star**
LCC Savings ($US)	$18	$32	$69	$89	$94
Payback Period (years)	1.4	2.7	2.7	2.7	2.8
Annual Energy Savings in 2035 (GWh)	3,263	9,170	19,840	25,522	27,829
Energy Savings through 2035 (GWh)	25,637	72,053	155,885	200,527	218,656
CO2 Emissions Mitigation through 2035 (MT)	21	60	130	167	182
Avoided Generation Capacity in 2035 (MW)	563	1,581	3,421	4,400	4,798
Net Present Value (Million $US)	1,098	2,048	4,466	5,767	6,110
Change in Industry Net Present Value (Million $US)	1.4	6.9	15.1	19.8	22.4

*Labels will only achieve a portion of the identified benefits compared to a MEPS

11 Complementary Program Designs

One of the greatest concerns within Indonesia regarding ambitious MEPS and labels is the first cost impact to price-sensitive consumers, and the investments necessary to produce more efficient equipment. This section explores a complementary policy package to MEPS and labels intended to drive cost down and encourage adoption of efficient technology by consumers, and identifies areas for technical assistance that would support Indonesian government priorities. The policy package includes the following options:

- Consumer awareness and education program
- Green Public Procurement
- Buyer’s Club programs
- Utility rebate programs and/or on-bill financing
- Manufacturer incentives

A comprehensive set of interventions, if implemented wisely, will activate a virtuous cycle that promotes innovation of new and efficient technologies, spurring economic growth (saving consumers money and manufacturers retooling costs), reducing peak electricity demands, and achieving environmental and health co-benefits (Figure 21, left)(Shaffie, 2010)[14]. Such a cycle lifts national development indicators while strengthening a country’s political and economic capital. In contrast, failing to implement these complementary policies will perpetuate a vicious cycle in which growth stagnates and the market is trapped in technology lock-in for decades (Figure 21, right).

[14] “The concepts in this section, particularly that of using a virtuous cycle to spur innovation, were first developed in a graduate thesis work, which was presented in 2010 at both the University of California-Berkeley and the Socio-Legal Studies Association."

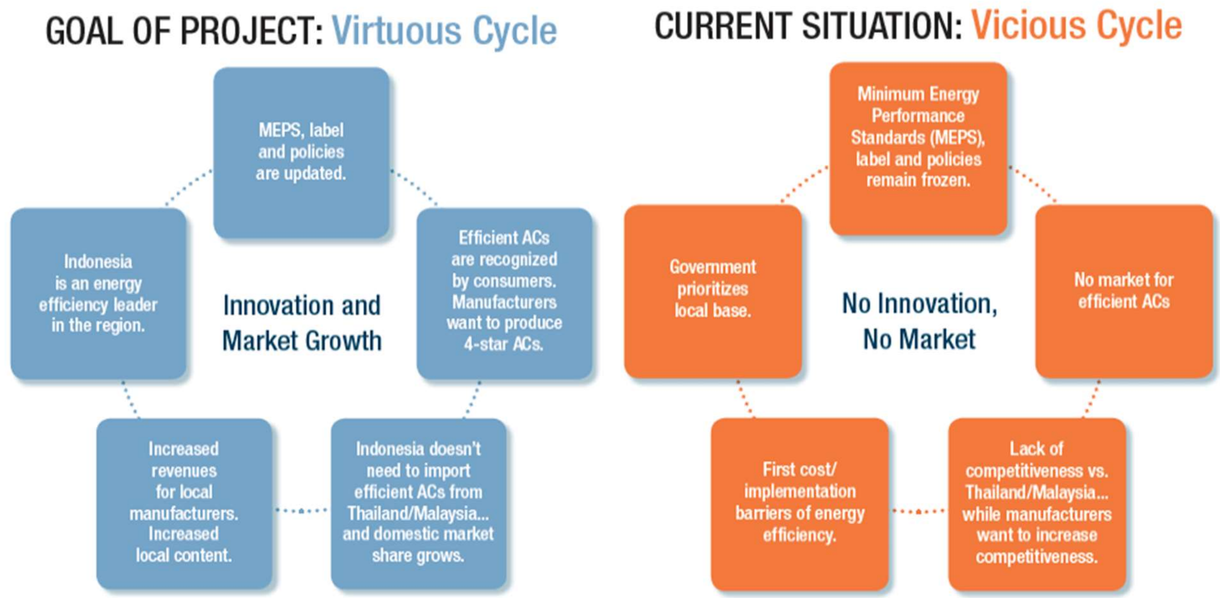


Figure 21. Virtuous cycle of high-efficiency AC innovation and market growth due to policies (left) vs. current vicious cycle resulting in no high-efficiency AC innovation or market in Indonesia (right) (Letschert et al., 2019) (Shaffie, 2010)

11.1 Consumer awareness and education program

To complement the increase in the MEPS and the rescaled 5-star label, Indonesia should implement large-scale consumer education and outreach on the many co-benefits of superefficient ACs. A significant barrier to efficiency after first-cost is lack of consumer awareness and education regarding the savings and environmental benefits of efficient ACs. Although Indonesian manufacturers have designed consumer education programs, these campaigns have achieved mixed success according to in-country interviews. Preliminary research demonstrates that government-led large-scale education, outreach, and promotion is critical to success.

11.2 Green Public Procurement

Green procurement is the process of obtaining services and technologies that are environmentally friendly while replacing outdated technology. Through green procurement, the Indonesian government can directly demonstrate the process and benefits of transitioning to high-efficiency ACs.

LBNL has identified multiple barriers to efficient ACs through manufacturer interviews. The primary barrier is the AC unit's first cost. The first cost of achieving higher AC efficiency can be incremental (see section 6). Superefficient levels can be reached with more significant increases in price, but these prices can be managed as the market reaches economies of scale (Taylor et al., 2015).

Requiring that the government purchase only the more efficient 5-star ACs could provide a guaranteed market to AC manufacturers, provide economies of scale for more efficient technologies, and reduce costs to all consumers of more efficient equipment. By encouraging domestic manufacturing of efficient ACs as well as reducing equipment imports, green public procurement could also reduce the government's current account deficit and increase revenue.

The Indonesian Ministry of Environment and Forestry (MOEF) has already announced a green public procurement (GPP) program, which refers to the label and ratings in current AC star-rating program effective 2017.[15] While this requirement could apply to both private and government buildings, it is intended to be mandatory for government buildings. The MOEF has created an inter-ministerial working group to implement the GPP program in progressive stages from 2020-2024 in various provinces. Given the early stage of implementation of the program, there is still an opportunity to harmonize the requirements with any revisions to the star-rating program made by MEMR.

11.3 Buyer's Club

Another way to create economies of scale and overcome the first-cost barrier is demand aggregation through buyer's clubs, which function as a "pull" mechanism, drawing the market toward efficient products.[16] A buyer's club is a coalition of willing purchasers who pool their resources to enhance buying power, driving down product prices by purchasing in bulk quantities. By enhancing manufacturer economies of scale, buyer's clubs can also make products more accessible and affordable to average buyers. Ideally, an AC buyer's club would support enough market demand to incentivize manufacturing of more efficient technology.

Designing a successful buyer's club requires identifying and aligning suitable entities as well as performing data-driven analysis to inform procurement. If successful, a buyer's club program enables policymakers or program managers to spur manufacturers toward setting lower prices, offering higher ELs, or both. The following are steps that could be followed to create a high-efficiency AC buyer's club in Indonesia:

1. Analyze the entire AC market and identify the largest buyers as candidates for club members.
2. Identify buyer characteristics, including hours and type of AC use (e.g., seasonal use), applicable electricity tariffs (residential, commercial), sensitivity to first costs versus long-term energy

[15] Ministry of Environment and Forestry Regulation NOMOR P.5/MENLHK/SETJEN/KUM.1/2/2019

[16] Buyer's clubs are one form of demand aggregation. Bulk procurement programs—such as India's Energy Efficiency Services Limited (EESL)—are another distinct form of demand aggregation (Abhyankar, Shah, Letschert, et al., 2017)

savings, needs, risk tolerances, and motivations. Identify: are they willing to aggregate their demand?[17]

3. Identify a government contact for the buyer's club that can facilitate the program.
4. Identify an entity to aggregate the demand, such as an industry association, quasi-governmental or public-private entity, or utility. This is often the most difficult part of forming a buyer's club. An ideal aggregator has the following qualities: (1) it can make the case for aligning buyer interests with the goals of a high-efficiency market; (2) it is trusted by key stakeholders such as high-use buyers, the utility, and the government; (3) it can bear risk and borrow capital; (4) it is unhampered by bureaucratic restraints.
5. Design the club's procurement based on the 5-star level in Indonesia's new AC S&L program.

For example, a buyer's club could be made up of a major hotel chain, which could be an ideal place for Indonesia to start. The hotels (club members) will likely have varying cooling demands based on seasonal changes. The level of AC efficiency would be selected based on hours of use, electricity bills, and savings targets. A hotel association could be the aggregator if it is trusted by both the hotels and the utility.

In this case, given that Indonesia has an already strong start to its GPP, it makes sense to coordinate the launch of a buyer's club in tandem with the government rollout of the GPP. For example, after steps one through three above, the facilitator can announce an initial public tender, which may include signing or publicizing high-level commitments to long-term efficiency targets. If planned in advance with the Ministry of Environment (the agency leading implementation of the GPP), the buyer's club launch timeline can dovetail with the launch of a government-led procurement with the same targets. Second, we suggest designing an awards program within the first year of the buyer's club, to build both public support and to create further buy-in from club members competing to achieve recognition. Creative potential should be encouraged at this stage, particularly because activities related to the buyer's club would likely have crossover appeal for government members who are also actively participating in the GPP, and can therefore strengthen support within the government for EE policies. When tied to the GPP, the co-economies of scale will build off of one another, and create momentum for the proposed new 5-star level.

If the buyer's club can be organized with energy efficiency requirements in common with other programs (e.g. the green public procurement program described herein) requiring that buyer's purchase only the more efficient 5-star ACs, this could provide a guaranteed market to AC manufacturers, provide economies of scale for more efficient technologies, and reduce costs to all consumers of more efficient equipment. By encouraging domestic manufacturing of efficient ACs as well as reducing equipment imports, such a buyer's club could also reduce the government's current account deficit and increase revenue.

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[17] Not all members will be uniformly interested in high efficiency. Some buyers will be in the electricity sector, some in the private sector—and interests may not align. In this case, an interim step of holding stakeholder meetings and creating buy-in is required.

LBNL is currently identifying factors to encourage an Indonesian buyer's club, and will continue to support government and private interventions in line with these recommendations.

11.4 Rebates and Other Utility-Based Programs

Along with providing incentives to manufacturers, policies such as rebates and utility programs can drive down the first-cost barrier for consumers while allowing utilities to meet rising electricity demand. This is particularly significant in Indonesia owing to its rapidly increasing AC consumption and higher peak demands. Reducing demand—including peak demand—is critical for Indonesian utilities.

Cashback rebates for purchasing superefficient AC units will help drive down costs and encourage consumer adoption of efficient technology. Utilities can subsidize energy-efficient technology for consumers that is then repaid through monthly installments. With such programs, consumers can be pulled toward energy-efficient purchases even without possessing full knowledge of the benefits. By encouraging domestic manufacturing of efficient ACs as well as reducing equipment imports, utility rebates could also reduce the government's current account deficit and increase revenue.

Ongoing analysis will determine which consumer incentives are helpful for Indonesia, particularly given recent changes after the April 2019 elections. LBNL will continue to engage and inform discussions with the Government of Indonesia, local manufacturers, and the State Electricity Company (PLN) regarding complementary programs that can most effectively transform the Indonesian AC market.

11.5 Manufacturer Incentives

Manufacturers are concerned with the upfront cost of innovating and updating their technology to make energy-efficient AC units. However, manufacturer incentives can be implemented to ease these concerns, including subsidies, rebates, or tax credits. These types of manufacturer incentives are designed to "pull" the market towards energy-efficient technology.

Government funding of manufacturer incentives can benefit both parties. Generally, taxpayers pay for government-funded programs, but government programs can also be funded with capital raised through bonds (De La Rue Du Can et al., 2011). A government bond offers a low, fixed interest rate that can be paid through the funds saved by energy efficiency (De La Rue Du Can et al., 2011).

LBNL is currently analyzing the best design for Indonesia-specific incentives that would benefit manufacturers (equipment redesign and retooling costs) and consumers (retail costs passed on from manufacturers). LBNL will also offer plans to incentivize manufacturers to adopt a roadmap for future revision of Indonesian MEPS and labels, as proposed in Table 21 and Table 22.

Including manufacturer incentives alongside labeling and MEPS in Indonesia removes the barriers that prevent manufacturers from innovating and updating their technology to create energy-efficient AC units. This will provide manufacturers with incentives that reduce their initial transition costs, and consumers will save by not having to cover those costs. Such incentives will enable manufacturers to sell energy-efficient ACs at around the same cost as former, less-efficient products.

After MEMR revises the current star rating program to 5-stars, we recommend that the government fund manufacturer incentives, for example, through reduction in value-added taxes (VAT) for energy efficient 5-star appliances (including but not limited to ACs) levied by the Fiscal Policy Agency or Badan Kebijakan Fiskal (BKF), a unit under the Ministry of Finance. By encouraging domestic manufacturing of efficient ACs as well as reducing equipment imports, such an incentive could reduce the government's current account deficit and increase revenue.

The Kigali Amendment Connection and recommendations on Refrigerant criteria

Within the past two years the Montreal Protocol (MP) Parties have explored funding, technology opportunities and challenges regarding energy efficiency in refrigeration and air-conditioning. The Quito Decision on Energy Efficiency was adopted in 2018, and allowed Article 5 (A5) Parties for the first time to use Montreal Protocol funds for energy efficiency activities, such as developing and enforcing energy efficiency policies and promoting access to energy efficient technologies for air-conditioning and refrigeration.[18] Separately, the Decision also continued the support of the MP for demonstration projects in A5 countries that improve energy efficiency during the refrigerant transition.[19] The Quito decision also directed the Multilateral Fund (MLF) to liaise "with other funds and financial institutions to explore mobilizing additional resources and, as appropriate, set up modalities for cooperation, such as co-funding arrangements, to maintain or enhance energy efficiency when phasing down HFCs".[20] It should be noted that although the MLF is a source of funds, it only funds the incremental cost of the transition for substances governed by the Montreal Protocol. As such, it is not a source of funding for energy efficiency, and is explicitly calibrated with technical requirements that parties must follow in order to gain access to funding. The MLF is only authorized to act from decisions that the parties to the Montreal Protocol make; currently that authority is only extended to the exploration of cooperative or co-funding arrangements.

While the debate about how to co-fund energy efficiency improvements while phasing down HFCs under the Kigali Amendment is evolving and ongoing, the Quito Decision presents an unprecedented opportunity for A5 Parties such as Indonesia to implement well-designed demonstration projects to showcase to other A5 Parties how to both (1) phase out medium to high-GWP refrigerants that contain HFCs, while simultaneously (2) increase the energy efficiency of AC equipment.

Therefore, Indonesia would benefit from setting a long-term GWP target consistent with the United Nations, U4E model regulation levels of 750 for split systems, and 150 for self-contained AC systems. A well-designed AC model need not trade-off between efficiency and refrigerant transition, since both R32 and R290 alternate low-GWP refrigerants[21] are more efficient than the baseline R410A and R22 refrigerants respectively. Transitioning simultaneously to low-GWP refrigerants along with implementing energy efficiency improvements for ACs is likely to keep implementation costs (and

[18] See Decision XXX/5 starting on Page 3 here: http://conf.montreal-protocol.org/meeting/mop/mop30/report/English/MOP30-compilation-of-decisions.pdf. Article 5 parties include developing countries; the rest of the parties are referred to as "non-Article 5 countries." The decision allowed A5 Parties "to use part of that support for energy efficiency policy and training support as it relates to the phase-down of controlled substances, such as: (a) Developing and enforcing policies and regulations to avoid the market penetration of energy-inefficient refrigeration, air-conditioning and heat-pump equipment; (b) Promoting access to energy-efficient technologies in those sectors; (c) Targeted training on certification, safety and standards, awareness-raising and capacity-building aimed at maintaining and enhancing energy efficiency."

[19] Id. "To continue supporting stand-alone projects in parties operating under paragraph 1 of Article 5 in accordance with Executive Committee decision 79/45."

[20] Id.

[21] While both R32 and R290 are alternative refrigerants, we note that R32 is 300 times more climate potent than R290.

therefore costs to the consumer) lower than implementing these separately. LBNL will further explore the potential for designing a project to demonstrate co-funding of energy efficiency improvement in ACs along with the transition to low-GWP refrigerants under the Montreal Protocol in Indonesia.

The recommendations for accessing MLFs comes with a caveat, that there are no existing examples or history of the Montreal Protocol itself granting funding to manufacturers for equipment energy efficiency upgrades. It is critical to follow the current debate within the Montreal Protocol and monitor the discussion on energy efficiency funding which is evolving.

That said, as mentioned above, the potential co-funding refrigerant transition and energy efficiency improvement under the Kigali Amendment is a good opportunity for Indonesia to design and propose a demonstration project that would improve energy efficiency in tandem during the refrigerant transition. A good model for this project design is the proposal developed by Indonesia in collaboration with the United Nations Development Program (UNDP)'s Global Environment Facility GEF-Climate Change Mitigation team to seek $5 million of funding from the Global Environment Facility (GEF).[22] The project "included technical and policy interventions, which would enable the Indonesian government and industry to enhance energy-efficiency of air conditioning and refrigeration equipment, contributing to Indonesia's voluntary CO_2 emission reduction targets by 2020.

[22] More details on the project are available at https://www.thegef.org/project/promoting-energy-efficiency-non-hcfc-refrigeration-and-air-conditioning-penhraresubmission

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